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THE LEHIGH UNIVERSITY,
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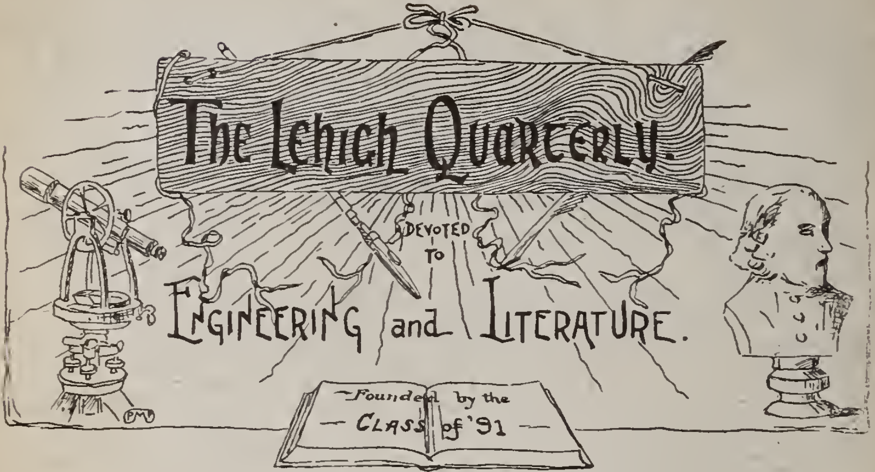

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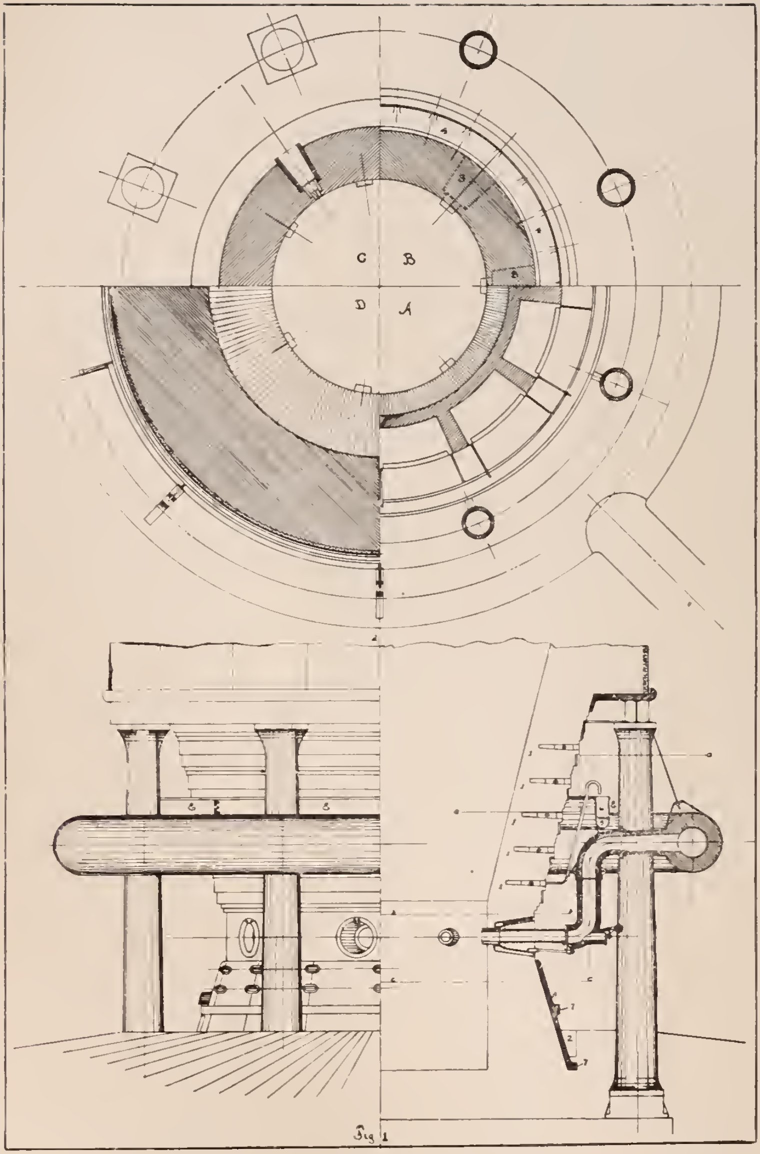

Fig 1

Vertical Section showing crucible and bosh,
and
the location of cooling devices in use about the furnace.

THE

LEHIGH QUARTERLY.

FOUNDED BY THE CLASS OF 1891.

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Vol. II. APRIL, 1892. No. 2.

WATER COOLING APPLIANCES IN USE AT A MODERN BLAST FURNACE PLANT.

Wherever high temperatures are necessary for the reduction of ores and the melting of the metal and cinder formed by the process a difficulty is encountered; for the materials of which we make the vessels and appliances with which the process is carried forward are themselves liable to fusion, or at least to a gradual disintegration, from the effects of their long exposure to such great heat.

Some method must be adopted to prevent or retard this destruction, and among other devices recourse has been had to water cooling. Not only is it necessary to protect the brickwork, but such parts of a furnace and its equipment as tuyeres, valve seats, and valves for hot gases, and the hot blast must also be cooled with water to preserve them from the warping action of the heat on the planed surfaces. Wherever there is danger from overheating, water cooling has been found a great advantage, and in the case of tuyeres and similar appliances that come in contact with the hot metal or cinder it is imperative. We propose here to describe such apparatus of this nature as is used at this plant. No elaborate description will be attempted, nor

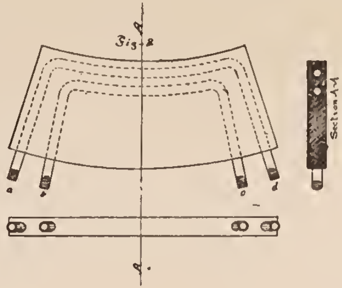


Fig. 2
A
A
a
b
c
d
Section A-A

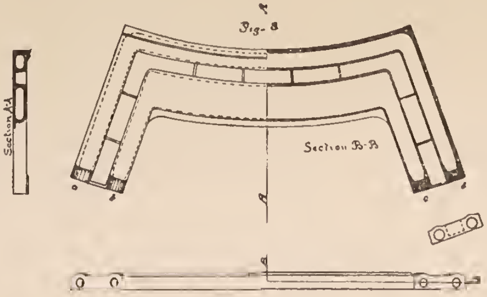


Fig. 5
A
A
A
Section B-B
Section A-A
a
b
c
d

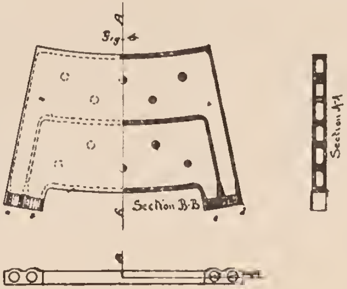


Fig. 4
A
A
A
Section B-B
Section A-A
a
b
c
d

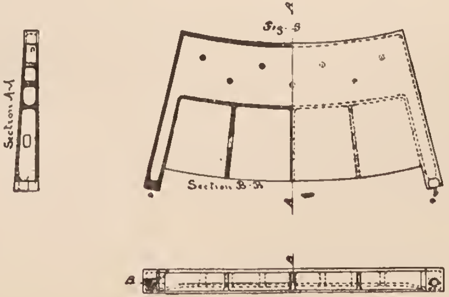


Fig. 3
A
A
A
B
Section B-B
Section A-A

has any effort been made to give a theory or theories for the action of such devices. We will divide these appliances into the following classes:

Bosh plates.
External jackets with coils.
Tuyeres and cooler.
Valve cooling apparatus.

The vertical section, Fig. 1, shows the crucible and bosh of one of our standard furnaces. The location of all the cooling devices in use about the furnace may be seen from the various sections given.

The bosh plates 1, 1, 1, are of the type shown by Fig. 5, and consist of hollow blocks of bronze, through which water circulates. This water carries away the heat transmitted from the interior of the furnace so rapidly that a comparatively low temperature is maintained in the brickwork in the immediate vicinity of the plate. They are built in the bosh wall in courses, there being usually five, at such distances apart that the cooling range of one plate shall not fail to extend in all directions to the area affected by those adjoining it. These distances are determined by practical experience. It has been found that when in courses 24″ above one another, and with 10″ to 12″ between successive plates of a course, good results are obtained. The arrangement (Sec. *A*) of plates in a course may be seen in Fig. 1, and the position of the courses in the vertical section.

We have in use four types of plates of this character. Fig. 2 is a cast-iron plate or block into which are cast pieces of wrought-iron pipe which serve as passages for the cooling water. The inlet is *a*. The water passes first through the pipe near the inner edge, *a* is connected by a union with *c* so as to return the water through the second or outer pipe to the outlet *b*. This outlet is often connected with the inlet of a plate adjoining it, for the water is rarely ever heated more than a few degrees in its passage through a plate. In fact, with these water cooling appliances the difference in temperature of the inflow and outflow is seldom known to exceed 5° F. Bosh plates are made to conform to the arc of the circular wall into which they are to be built. The plate is laid with its edge flush with the outside of

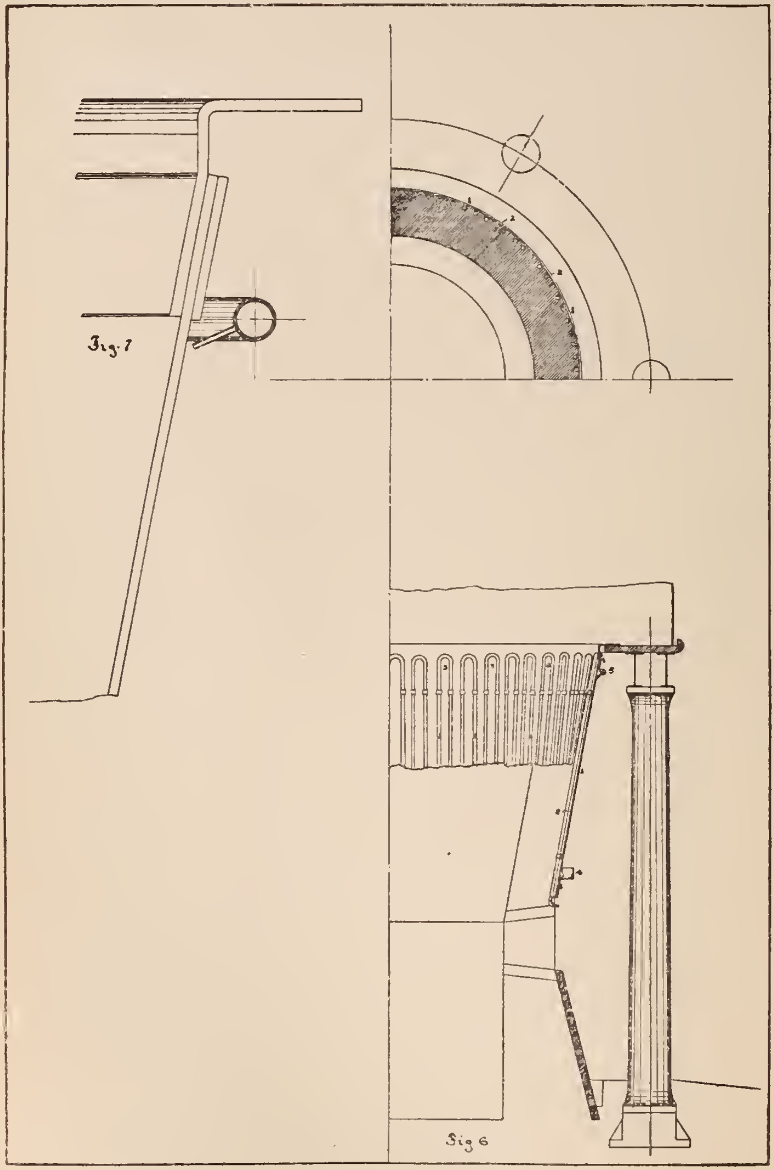


Fig. 7

Fig 6

the wall and the width is such as to keep at least 4½″ and sometimes 9″ between the inner edge and the interior of the furnace. Usually the plate is 2½″ thick, so that it may be built in a regular course of brick.

The plate, Fig. 2, is employed at present to a very limited extent, more efficient types having taken its place. These new types are made of bronze for several reasons. Bronze is a better conductor of heat and therefore the transfer of heat to the water is more rapid than with iron. Being a better conductor, there is much less danger of overheating and losing the plate. Lastly, the amount paid by dealers in scrap is much greater for bronze than for iron when taken as the percentage of first cost. Cast-iron plates with wrought-iron coils have therefore made way for the bronze plate, and Fig. 3 is one of the first types which came into use. It will be readily seen that there are two passages for water connected in the same way as those of Fig. 2. It will be noticed that one passage is much smaller than the other. The inner passage is contracted so that the velocity of the water will be great where the heat is most intense and thus make it impossible for any water to lie stagnant, besides giving a large quantity of water in a given time to each unit of surface exposed.

Fig. 4 is a plate used in the brickwork of the crucible or well, placed between the tuyeres and at the same level. The water surface is very great, being almost that of the whole plate. Fig. 5 is a bosh plate of a rather peculiar design. It is made wedge shape, making it easily withdrawn and replaced. It has a single broad passage, which is supported by studs against the weight of brick above it. The plate is laid with the top horizontal to prevent any air from accumulating in the point, *c* Fig. 5, and by preventing contact with the water, allowing the plate to burn. Single passage plates are more economical than the double passage type, for with the latter it is customary, when the inner passage is injured, to shut off the water and allow it to burn away, using only the outer course. This involves a great loss of metal, and since this metal is bronze the expense is great. The bronze walls of the plates vary from five-sixteenths to three-fourths of an inch in thickness, the average, however, being three-eighths of an inch. No class of plates, however, is entirely free from leaks,

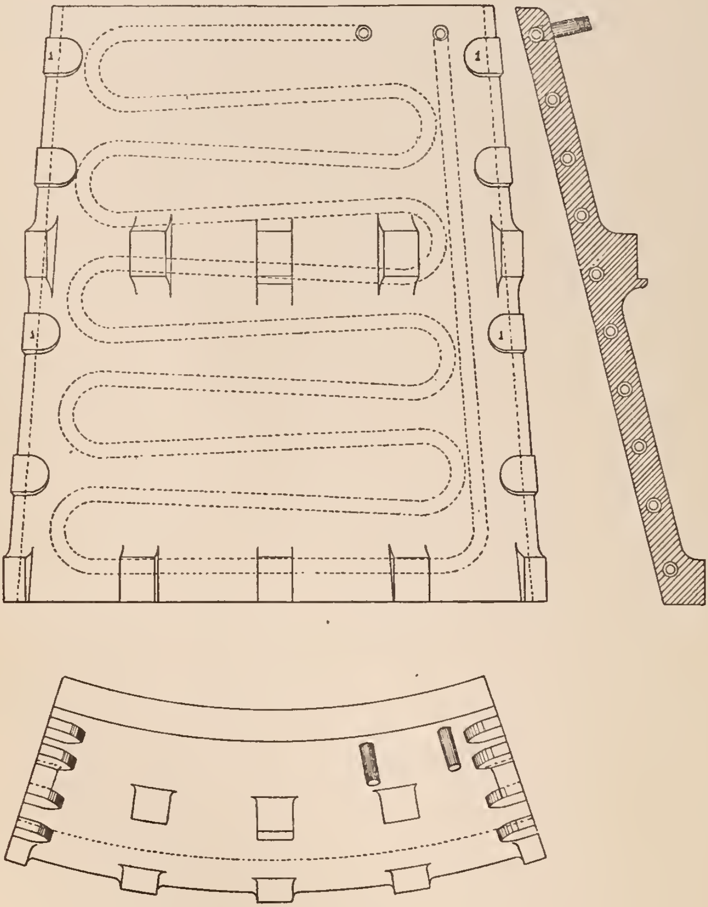


Fig. 8

due either to flaws in the metal opened up by the heat or to the walls being corroded by the action in the furnace to such an extent as to allow liquid cinder or iron trickling down to come in contact with the edge of the plates and in time burn them.

A leakage is at once detected by the escape of gas with the overflow from that plate and also by the decrease in the amount of overflow. To prevent the water flowing into the furnace the head to which the water in the plate is subjected is reduced by directing the overflow into the gutter 2, Fig. 1. Sometimes the heat that produces the leak will in time so melt the metal down as to close it. Should the plate be burnt beyond repair, it is removed from the bosh and a new plate inserted. Before a new plate is put in the water connections are made, so that there shall be no danger of burning it during the time that would elapse after it is in position until it is connected with the water pipes. There is a disadvantage in the use of bosh plates claimed by the opponents of this practice. Where the cooling effect is least the wear is the greatest. The brickwork is worn away between the courses of plates, so as to produce a wavy line, which hinders the even, downward path of the stack. By keeping the plates at the distance apart that we do, these irregularities have not affected the running appreciably. If we keep the whole body of the brickwork equally cool we will have a uniform wear. Bosh jackets, Fig. 6, have been used for this purpose and also as an additional safeguard on furnaces where there is danger of a "breakout" from the use of a mixture that has a very corrosive action, or where the temperatures used are very high, as, for example, on spiegel and ferro-manganese furnaces. This jacket is built of wrought-iron or steel plates and bands, 1, 1, 1, Fig. 6, riveted together, and to its interior are secured coils of wrought-iron pipe. These consist of twelve straight sections of pipe, 2, 2, 2, Fig. 6, connected by *U* bends, 3, 3, 3, Fig. 6, the inlets and outlets extending below the edge of jacket to facilitate connection with the water pipes. There are eight of these coils, making in all 96 sections of pipe 1¼″ in diameter placed about 5″ apart. This jacket is suspended from the mantel-plate of the furnace and the brickwork is built up within it close to the coils, the space around the coils being filled with brickdust and mineral

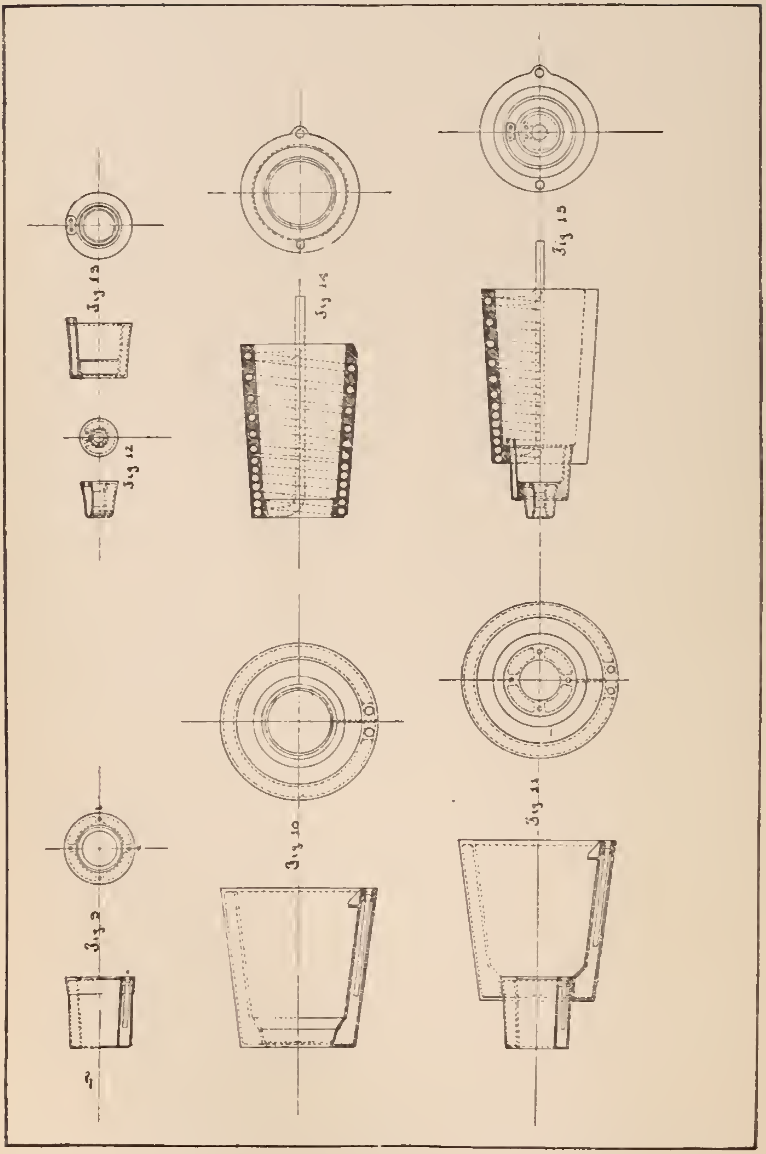


Fig 9
Fig 10
Fig 11
Fig 12
Fig 13
Fig 14
Fig 15
9

wool. The thickness of the wall in this case is less than in the other furnaces, for it has been found useless to build the wall of a greater thickness than that to which it would eventually wear before being stopped by the cooling action of the jacket.

In time these coils become burnt, corroded, and leaky, so that the water has to be shut off, and were it not for another device the walls of the bosh might become overheated and fail. To supplement the action of the coils or to fill their place when they are destroyed, a spray pipe, which encircles the upper part of the jacket, is employed to throw water upon the outer surface, which, streaming down the plates of the sides, keeps them and the brickwork on their interior cool. The circular trough 4, Fig. 6, at the base of the jacket, catches the water and outlets are provided to carry it away. The arrangement of the spray pipe is shown by 5, Fig. 6 and Fig. 7. This pipe is divided into a number of sections, so that any part of the jacket may be sprayed as necessity requires.

It is not the bosh only that requires cooling. The well or crucible must be protected, particularly the upper part in the neighborhood of the tuyeres, which is subjected to the highest temperature occurring in the process. This is done by means of the plates, Fig. 4, and the coolers, Fig. 10, and 3,3, Fig. 1, Sec. B, are of service in this direction. The crucible proper, in which are contained the cinder and iron, is cooled by the jacket 4,4, Fig. 1. This is made up of sections of cast-iron plates with wrought-iron coils cast in them. Fig. 8 gives a single section. This jacket resembles the surface of a frustrum of a cone, the object of this construction being that as the brickwork of the hearth and well expands, instead of bursting the jacket, it will ease itself by slipping up on the outside wall of the well. The angle of the jacket is about 75°. The sections of the jacket are secured to one another by links which fit over the lugs 1,1,1, Fig. 8, of two adjacent plates, and the jacket is encircled by two wrought-iron bands, 77, Fig. 1, as an additional precaution.

Openings are made for the tapping hole and cinder notch, these being cast in separate special sections. The coils of two adjoining sections are coupled together. The brickwork of the floor is built around the lower part of the jacket so as to form a gutter 2,

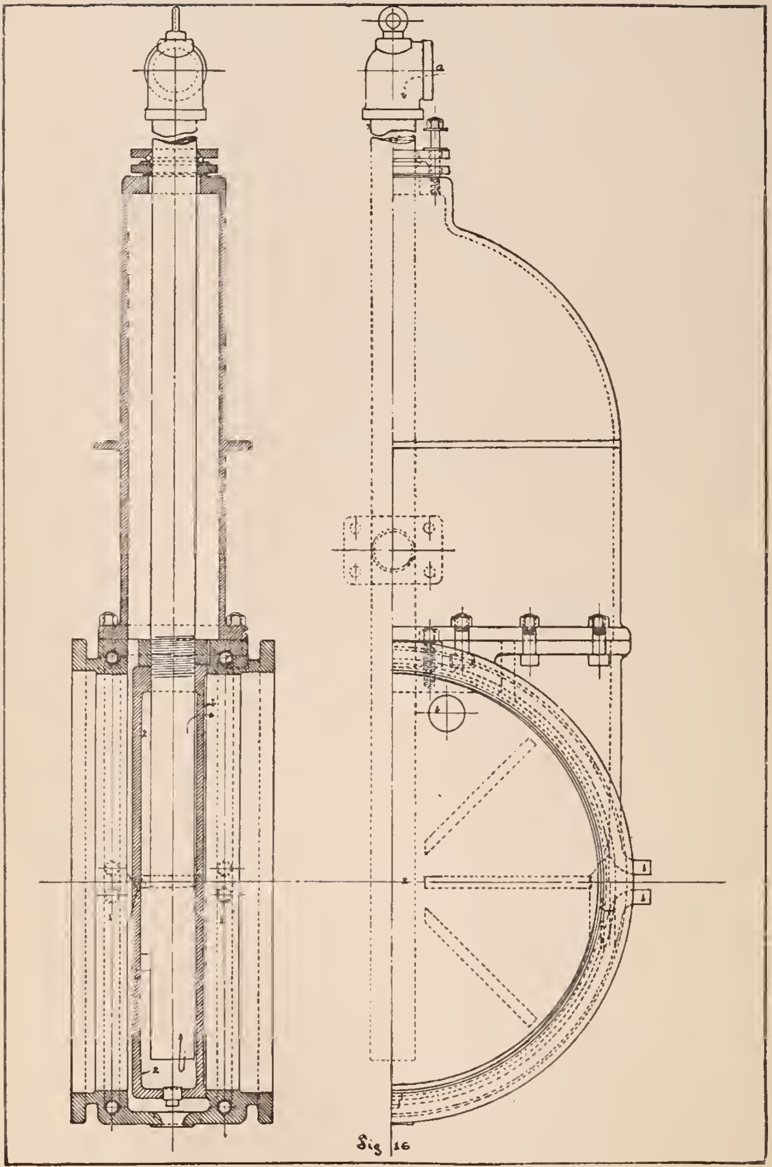


Fig 16

Fig. 1, and into this a part of the overflow is directed and, surrounding the jacket, helps to keep it cool. The plates of the jacket are of cast iron 3½″ thick. The coils are made of heavy wrought-iron 1¼″ pipe. The vertical height of the jacket is about 6 feet. The bronze tuyere through which the hot blast is supplied for the combustion of the coke is subjected to the most severe service of any of the cooling devices about the furnace, and special precautions must be taken to prevent its destruction. The water supplied to it is of higher pressure than is used on the plates, etc., 40 lbs. per square inch being carried in the tuyere feed pipe, while 20 pounds per square inch is sufficient for ordinary uses. The high pressure in the case of tuyeres is intended to act as a safeguard against any deposit forming in the tuyere or in case of any obstruction to force it out, for should a stoppage occur but for a moment the tuyere would be immediately burnt out.

Referring to Fig. 9, it will be seen that to the inlet *a* is screwed a piece of brass pipe which directs the water well toward the end of the tuyere. This gives the benefit of the cold water where it is most needed and prevents its immediate escape by the outlet *b*, to which it would otherwise go as the shortest way out. Good circulation is thus insured and very little trouble is experienced with burnt tuyeres. However, in case of a burnt tuyere, removal is rendered easy by having the tuyere fit into a metal seat on the cooler (see Fig. 10). This cooler of bronze, Fig. 10, is similar to the tuyere in the method of cooling employed. Its object is to provide a permanent and durable seat for the tuyere, as near the interior of the furnace as possible.

For the cinder notch a somewhat similar arrangement has been adopted. It consists of three parts, known as the monkey (Fig. 12), monkey cooler (Fig. 13), and cinder brest or cast-iron cooler (Fig. 14). The monkey and its cooler are of bronze. The monkey has a nozzle about 2 inches in diameter and through this passes all the cinder flushed between casts. Fig. 15 gives the relative position of the parts of the cinder notch, and section *c*, Fig. 1, shows its position in the wall of the furnace crucible. To supply water for these appliances and to carry away the overflow, the combination pipe and trough *e*, Fig. 1, is used. It is made up of cast-iron sections, which together encircle the furnace. The

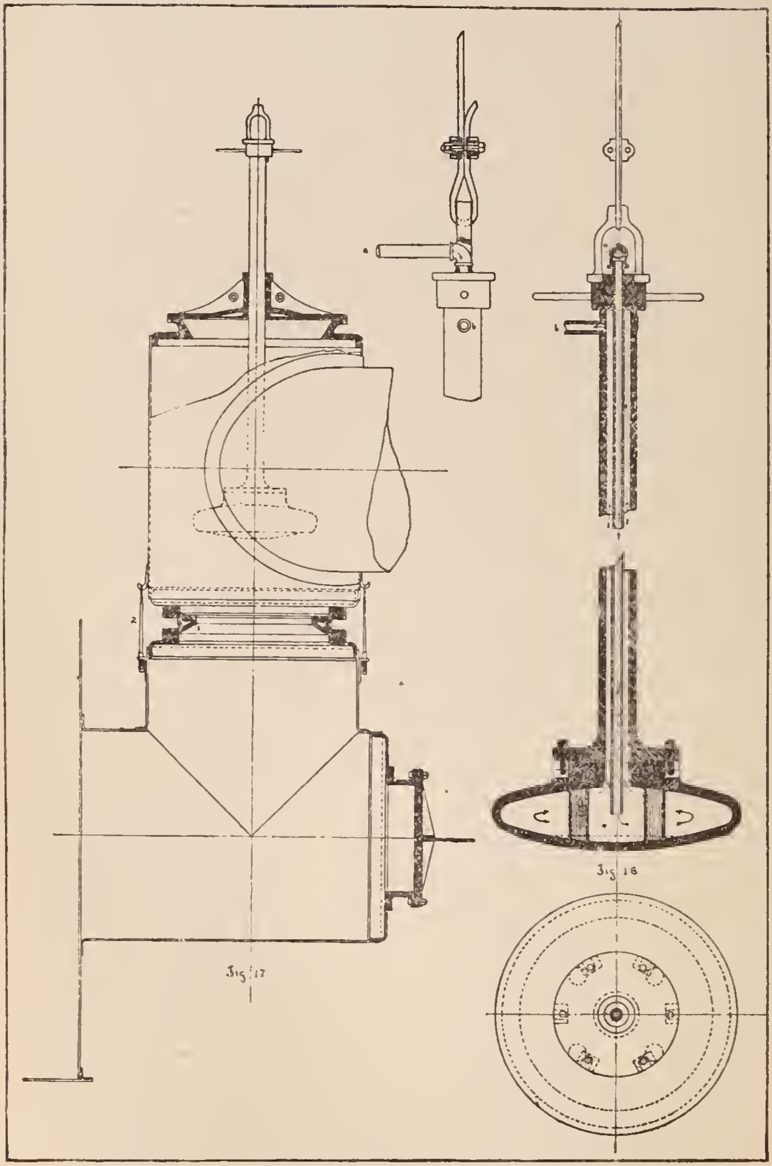


Fig 17

Fig 18

lower part, 5, contains the feed water and 6, the the upper part, is an open trough into which the overflow pipes discharge. The bottom is pierced with holes from which lead the inlet pipes for the plates, etc. The outlet pipes run up above the trough, where they are bent down to deliver the water into it. The tuyere feed is separate and consists of a wrought-iron pipe with cast-iron branches fitted at the proper intervals.

We come finally to the water cooling appliances in use on the hot-blast stoves. These are the chimney and hot blast valves. The chimney valve (Fig. 16) is a combination of water cooling and air cooling. The coils 1,1,1,1, are cast in the body and one of these cools the valve seat with water. The draught induced by the stack sucks air in at *a*, it passes down the stem and discharges into the hollow gate or disc, absorbs its heat, after which it escapes through the holes *b*,*b*, to the stack.

The hot-blast valve (Fig. 17) is entirely water cooled. The valve and its stem are shown in detail by Fig. 18. The inlet water carried by a hose, to allow of vertical movement to the valve, is admitted at *a* and follows the course indicated by the arrows, discharging finally through the outlet *b*, where it is conveyed by a hose to the waste pipe. Both valve and stem are of cast iron, the central inlet being wrought-iron pipe. The valve seat 1, Fig. 17, is made of bronze. This seat is shown in larger scale, Fig. 19. The heads of the valve chamber are *a*,*a*,—*b*,*b*, steel rings riveted to these heads, *c*,*c*, the bronze valve seat—*d*,*d*, the actual seat or surface in contact with valve *e*,*e*, the water passage, and *f* and *g*, the inlet and outlet respectively.

In order to prevent leakage between the ring *b* and the flange of the seat *c* in contact with it, this upper steel ring *b* is provided with slotted pockets for T headed bolts, which fit in corresponding slots in the flange of the seat and allow of these two surfaces being firmly pressed together. The seating of the valve tends to push these surfaces apart. These bolts prevent this. The upper half of the top view (Fig. 19) shows the pockets and slots in the steel ring *b* and the lower half of the corresponding slots in the top flange of valve seat.

The lower ring is made to bear on the lower flange of the seat by means of the key bolts 2, Fig. 17.

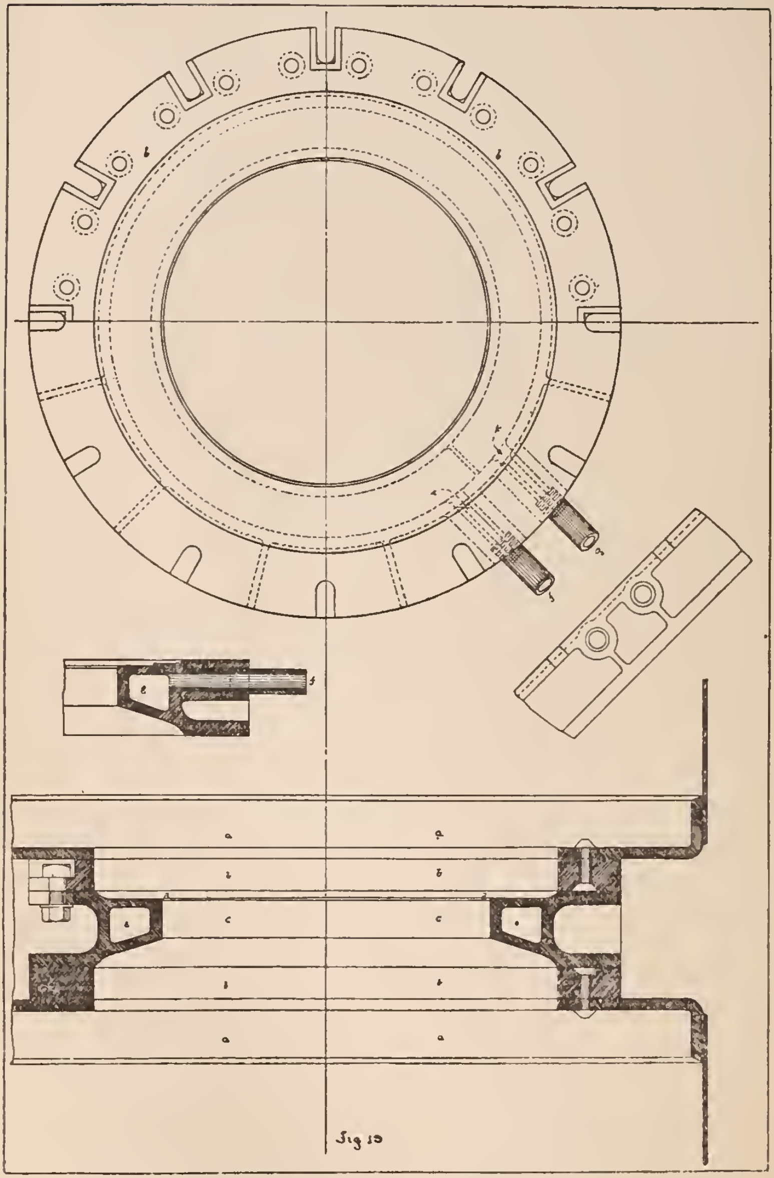


Fig 10

In conclusion it should be mentioned that, notwithstanding the advantages arising from cooling devices, yet many of these appliances would be comparatively worthless were not the suction pipe of the supply pump provided with a fine mesh screen, for fish entering would clog the pipes supplying the bosh plates, an accident which has been found in several cases to be the immediate cause of their being burnt.

FRANCIS DU PONT THOMSON, '90.

NOTES ON BOILER WATERS AND ON THE INCRUSTATIONS RESULTING FROM THEIR USE.

All natural waters contain more or less mineral matter, acquired by contact with the earth's surface and by percolation through its soil and rocks. This mineral matter is partly in solution and partly in a state of suspension. The ratio of the two varies a great deal, and is dependent on the character and source of the water, and on the state of the weather and other local reasons. In general, however, it may be stated that spring water, well water, creeks, etc., contain much more matter in solution than lake and and river water. Lake waters are usually pure. River waters vary much in composition, as in the course of their journey to the sea many kinds of earth are passed over. They rarely contain more than eight grains of mineral matter per gallon in solution, but the amount in suspension is variable. The reverse of this is true of spring and well waters, as they have been filtered by percolation through various strata and are consequently low in suspended matter, but high in their contents of mineral ingredients in solution. This is not often less than ten grains per gallon and under certain circumstances may rise enormously above this limit.

The mineral matter in solution consists mainly of calcium carbonate, magnesium carbonate, calcium sulphate, oxide of iron, alkalies, and silica. The solids in suspension usually consist of clay, sand, and vegetable matter. There are sometimes varying amounts of other substances in solution, but those just mentioned comprise almost entirely the boiler incrusting ingredients.

As the water in the steam boiler becomes concentrated, the order of depostion of these impurities is as follows:

(1) Calcium carbonate.
(2) Calcium sulphate.
(3) Oxide of iron and magnesia.
(4) Silica and alumina, usually with more or less organic matter.
(5) Alkaline salts.

Calcium carbonate is the first to deposit, as it is held in solution by the excess of carbon dioxide dissolved in the water, which is expelled by mere boiling, leaving the greater part of the calcium carbonate insoluble. At the temperature and pressure ordinarily reached in boilers it may be regarded as entirely insoluble. It deposits (especially when in large excess) as a loose, white, amorphous powder, which readily forms a sludge with the water. This will remain soft for a considerable length of time and when not exposed to too high a temperature, while emptying or drying the boiler, will be converted into a fine, flowery powder of a light color. If the boiler be blown out while the plates and brickwork in the flues are at a high temperature, the sludge becomes baked hard A considerable amount of incrustation from both calcium carbonate and sulphate may be directly traced to this cause.

Calcium sulphate has its greatest solubility at 95° F., when it dissolves in 393 parts of water. The solubility gradually decreases with an increase in temperature or pressure. At 212° F. it is soluble in 460 parts of water, at a temperature of 255° F., or a pressure of 30 pounds, its solubility is diminished three-fourths, and in water under pressure and at a temperature of 290° F. it is completely insoluble. Both calcium sulphate and calcium carbonate are completely precipitated merely by the elevation of the temperature of the water when the boiler is worked at 60 pounds pressure. If these substances are allowed to separate slowly from the water, they become partially crystalline and possess the power inherent with all similar crystalline precipitates, of firmly adhering to the boiler surface. If their rapid precipitation is effected, they separate in an amorphous, non-adherent form which may be easily removed from the boiler. The incrustation preventatives best adapted for use with water high in calcium sulphate depend upon this fact for their efficiency.

Magnesium carbonate, in its solvent action and precipitation, is similar to calcium carbonate.

At about this point the oxide of iron and alumina separate, the latter usually with more or less organic matter. In the inverse order of their solubility all the other salts separate and in much the same way as calcium carbonate and sulphate, except that, owing to their greater solubility, much more evaporation is necessary for their deposition.

After precipitation, the insoluble salts remain for a long time suspended in the water, and tend to deposit themselves more or less rapidly according to the density of the water, the manner in which it circulates, and the intensity of the ebullition. Where this is rapid the salts are held in suspension by agitation until the boiling ceases. Where the circulation is good they are carried away with the currents until a comparatively quiet part of the boiler is reached, when they are deposited upon the plates or tubes or in some of the mechanical devices used for the purpose of catching the precipitated sediment. The plates over the fire are not (as many naturally suppose) as liable to become encrusted as other parts of the boiler. The precipitated matter is held in suspension by the agitation consequent upon such rapid ebullition at this point, and is allowed to deposit in the cooler and more quiet parts. Very often incrustation in this part of the boiler is due the fact that pieces of scale become detached from the upper shell of the boiler and fall upon the plates in pieces too large to be carried away by the currents. The feed pipe (when the feed is cut off) is one of the quietest spots in the boiler, and hence the amount of deposit very often found in it. With waters highly charged with calcium carbonate or sulphate, the sudden change of temperature and pressure, to which the feed water is subjected, causes an almost instant precipitation of the calcareous salts, thus "furring" up the pipe and, in course of time, completely filling it. The deposit of scale, once having formed within the boiler, becomes thicker and harder, until it is as dense as porcelain and has reached such a thickness as to prevent the proper heating of the water by any fire that can be placed under it. The high temperatures necessary to heat water through the thick scale will sometimes convert it into an absolute glass by combining the sand with the alkaline salts.

The evil effects of scale are mainly due to the fact that it is relatively a non-conductor of heat. Its conducting power compared to that of iron is approximately in the ratio of 1 to 37.5, which ratio naturally increases as the scale thickens. It has been demonstrated that a scale one-sixteenth inch thick demands an increase of 15 per cent. more fuel, one-fourth inch thick demands an increase of 60 per cent. more fuel, and one-half inch thick 150 per cent. more fuel. These facts are not invariably true, as many boilers have incrustations considerably more than one-half an inch thick over the greater part of their heating surface without demanding anything like 150 per cent. more fuel. Practically, it is not an easy matter to calculate the actual loss of heat due to the formation of incrustation, inasmuch as the circumstances which determine the rate of heat transmission through plates covered by scale of different kinds and thicknesses (either homogeneous or otherwise) are not sufficiently understood to enable the theoretical results to coincide with those obtained in practice. Experience has shown that 45 per cent. of the fuel burned under locomotive boilers is required to overcome the non-conducting power of the scale.

There is still another point of view from which we can obtain an idea of the non-conducting power of boiler incrustations. In order to raise steam to a pressure of 90 lbs. the water must be heated to a temperature of 320° F. . This can be done in a perfectly clean boiler by maintaining the external surface of the shell at a temperarure of 325° F. If one-half inch of scale intervenes between the shell and the water its conductivity is such that it will be necessary to maintain the shell at a temperature of 700° F., or a low red heat. Abstractly, then, to raise water in a boiler to any given temperature, the fire surface must be heated to a temperature which will be in an increasing ratio with the thickness of the scale.

The greater the intensity of the heat to which the boiler shell is subjected the more rapid is the oxidation of the iron, and at any point above 600° F. it soon becomes granular and brittle and is liable to bulge, crack, or otherwise give way to the internal pressure. The expense incurred by the formation of scale is evident: (1) The raising, maintaining, and lowering of steam is rendered slower and more difficult, and (2) its presence is always attended with more or less overheating, with the consequent decrease in the length of life of the boiler. Explosions may also be directly attributed to the scale. The shell of the boiler becomes intensely heated, the scale cracks, and the water suddenly comes in contact with the hot surface. An immense amount of steam is almost instantly generated and consequently an explosion occurs.

There are other causes which tend to produce overheating besides the coating of incrustation within the boiler. The evil is very often due to the presence of a loose, impalpable powder, of which calcium carbonate is the chief constituent. This is long held in suspension and covers the water with a kind of scum, which, when present in any considerable quantity, offers great resistance to the escape of the steam bubbles and to the free convection of heat. The water is in consequence lifted off the plates by the steam that accumulates in their surfaces and allows them to become overheated. The presence of grease also tends to aggravate overheating. It acts mechanically with the calcium carbonate, causing it to settle in a loose, spongy mass, too inert to be carried away by the circulation or ebullition which it retards, and by preventing the contact of the plates and water, and also by offering great resistance to the transmission of heat, allows the plates to become overheated. A compact, homogeneous mass of incrustation should prove less detrimental to the plates exposed to the action of fire than a spongy, less solid or powdery mass. This is easily accounted for on the principle that loose sand forms a much worse conductor of heat than the solid stone of which it is composed.

Boiler incrustations may be more or less definitely divided into the following general classes:

(1) Those which are hard, compact, crystalline, and composed of numerous thin layers. This is the form of incrustation most common in locomotive boilers and is the type of the so-called "hard sulphate scale." They usually consist of from 30 to 70 per cent. of calcium sulphate associated with calcium carbonate and

basic carbonate of magnesia ($2MgO.CO_2$). On examination it is found that the strata of this type of boiler incrustation are partly crystalline and partly amorphous, varying in thickness from that of paper to ⅛ inch or more. Interspersed between these hard layers are frequently found thin, soft layers of earthy matter which has been held in suspension and deposited when the agitation of the water has temporarily ceased. The side of the crust nearest the heating surface is very often of a dark color, due to the presence of an excess of oxide of iron occasioned by the corrosion of the boiler shell.

(2) Those which are loose and friable, not at all crystalline and with no well defined layers visible. Calcium carbonate is the main constituent of these incrustations.

(3) Deposits consisting of a fine powder or mud. Their composition is variable.

We have now dealt with a few of the more important evils resulting from boiler incrustation. There is still another manner in which boilers may be injured by the feed water and the causes of the injury are in many respects the exact reverse of those already considered in connection with incrustation. In many cases boilers are subjected to as much danger from corrosion as they are from the excessive formation of scales.

When a very pure water is allowed to act on an entirely new boiler, corrosion rapidly sets in, owing to the presence of oxygen and carbon dioxide dissolved in the water; and this corrosion is all the more rapid, as there is so little mineral matter with which the gases may combine. The usual corrosive ingredients in waters are sodium and potassium sulphates and chlorides, and magnesium chloride. Their corrosive action is all the more noticeable when the water is highly charged with air and carbon dioxide. That these substances do attack iron is shown by introducing slips of iron and copper, connected with a galvanometer, into their solutions. The evil of corrosion is most noticeable with low pressure compound engines, which recondense their water.

The injudicious use of brass cocks and connections bolted or fastened to the boiler shell has often resulted in corrosion, due to the galvanic action at the points of contact of the iron and brass. Another cause of this danger may be attributed to a deposit of soot which is sometimes allowed to form in the tubes and flues, and which becomes charged with pyroligneous acids. This is frequently the case when wood has been freely used in lighting fires, or large quantities of coal have been fired at a time. An excess of pyrites in the coal will also occasion corrosion of the tubes. Corrosion is often caused by grease which may sometimes get into the boiler. This is particularly so in ocean steamships where the water is condensed by means of an injection condenser. The grease forms a lime soap at about 70° C. and this is rendered possible as a portion of the lime salts have separated in an insoluble form at this temperature. The lime soap, under the influence of a higher temperature, partially decomposes into free-fat acid and a basic lime soap, which adheres to the boiler surface, while the fatty acids attack and dissolve the iron.

From the foregoing principle of incrustation it is plain that it is in those *land* boilers only which use pure, natural water that we are likely to find corrosion actively at work. Calcareous or chalybeate water prevents its action. In a case where a remarkably pure water is to be had, it is well to add a little whitewash to the feed water, or the boiler may be fed for a few weeks with a calcareous water and then started on pure water. In this way we produce a thin, artificial layer of incrustation and the boiler is permanently protected from such corrosion.

We have now made a short review of the subject of boiler incrustation and corrosion and will proceed to the discussion of their prevention.

The methods resorted to for the prevention of corrosion and incrustation in a boiler are manifold and widely different in their nature and action. The following classification has been adopted and includes, more or less completely, all the common methods in use.

(1) Chemical treatment of the water before entering the boiler.

(2) Introduction into the boiler of chemical agents with the object of rendering the impurities of the water more soluble, or of otherwise changing their character and behavior.

(3) Various mechanical devices.

(1) Clark's process is one of the oldest and best known of the methods in use for softening waters, and is especially adapted to

waters containing much calcium carbonate in solution. The water is treated with milk of lime, which takes up the excess of free carbonic acid and converts the acid calcium carbonate into the neutral carbonate, which is insoluble and precipitates. The reactions involved are:

$$Ca(HCO^3)_2 + Ca(OH)_2 = 2\,CaCO_3 + 2\,H_2O.$$

This process is cheap and for some waters very efficient. Its great objection is the length of time required for the precipitated matter to settle. This can not be done in less than 24 hours, and for railroad use where so much water is consumed enormous storage tanks would be necessary. This expense and inconvenience renders the process almost totally useless for such service.

Another process proposed by Dr. Rogers consists in converting the earthy carbonates into soluble chlorides and then neutralizing the slight excess of hydrochloric acid by filtering through coarsely powdered witherite. The solution of barium chloride thus formed converts the calcium sulphate present into barium sulphate and calcium chloride, the former settling readily and the latter being very soluble. The process is cheap and simple and should be of service to railway stations.

There is another process, in which barium hydrate is used. This acts towards calcium acid carbonate in a manner exactly analogous to milk of lime and has the additional advantage of decomposing calcium sulphate. The precipitates formed are much heavier than those produced by Clarke's process and consequently settle in less time. The most serious drawback to the use of this reagent is its expense.

There are other processes intending to soften water before its entrance into the boiler, but all are more or less expensive and inconvenient. It is more practicable to one of the methods described in the following class of chemical agents acting within the boiler.

Commercial soda ash, on account of its wide applicability and usefulness to different kinds of boiler feed water, is, perhaps, deserving of first mention under this class. It is composed mainly of neutral sodium carbonate with a small percentage of caustic soda. Both calcium carbonate and sulphate are rapidly precipitated by its action. Soda ash decomposes calcium sulphate with an interchange of acid radical, the products of the decomposition being insoluble calcium carbonate, and the readily soluble salt, sodium sulphate. It mainly owes its efficiency to acid calcium carbonate by virtue of the small amount of caustic soda associated with it, which readily removes the excess of carbon dioxide from the water, precipitating normal calcium carbonate. With proper precaution the precipitated carbonate of lime can be readily removed, as has already been mentioned in regard to the properties of this substance when chemically precipitated.

If lime salts are largely present the use of soda should always be accompanied by frequent and regular blow-outs, to prevent foaming or "priming" within the boiler. This is by far the greatest objection to the use of soda ash. It can, however, be overcome by care and attention. The danger is naturally greatest when the boiler is first started on the use of the compound, and no amount of chemical analysis and calculation can entirely foretell, meet, and overcome the evil of priming. In a short time the boiler will usually become more settled in its action, and the engineer accustomed to exert the same watchfulness in the use of the boiler compound as is necessary for every successful manipulation of motive power. In most cases the evil is overcome or lessened below the danger limit by strictly confining the amount of soda used to that found necessary by an analysis of the water. If the boiler can be kept in good condition by a less amount than this it is always advisable to do so, as the expense is less and another evil which often accompanies priming is likewise reduced.

The oil used for the lubrication of steam cylinders usually consists of a petroleum oil of high viscosity or "body," compounded with from 10 to 25 per cent. of animal fat or oil. When the boiler primes, water is mechanically carried over with the steam, and, of course, the soda, being in solution, is more or less carried over with it. At the temperature of the cylinder the saponification of the animal oil rapidly takes place. This is especially true if the saponifiable matter contained any considerable admixture of free fatty acid. The resulting soap forms very hard, dark-colored lumps, which may endanger the safety of the cylinder or its valve.

Another source of trouble which accompanies the use of many of the compounds of this class, which is not peculiar to soda, is the liability of the plates to become overheated, due to the thickening of the water from the accumulation of precipitated mineral matter, or from the settling of a large quantity of deposit on the plates when the water is allowed to remain at rest, as at feed times.

These objections would appear amply sufficient to forbid the use of soda as a scale preventative. And we must admit that the objections are true. But that they may be overcome will be illustrated presently by quoting some experiences met with in its practical application in locomotive boilers.

For a water containing about seven grains of incrusting ingredients per gallon the following directions will usually insure satisfactory results: Use one pound soda ash per 1000 gallons of water and blow off the boiler after every 125,000 gallons have been consumed. If the boiler primes under this treatment gradually lessen the amount of soda used until the priming ceases. The best method of using the soda is to dissolve it in water and introduce it continuously with the feed. This can be done by connecting the vessel containing it with the suction pipe of the pump which supplies the water.

Soda ash is sometimes said to occasion corrosion, but the belief is usually founded on the fact that its use simply enables the defect in the plates to be seen which were hitherto unsuspected. Its tendency is just the reverse, and checks the corrosive action due to the presence of magnesium chloride, alkaline salts or any organic acids.

Sodium and potassium hydrates act somewhat similarly to soda ash, but are said to have a slight corrosive action when concentrated. They remove hard, sulphate of lime incrustations more rapidly and should be employed in small quantity. It must be remembered that in the use of the alkaline hydrates and carbonates, the sole object is the modification of the nature of the incrustation without, in any way, preventing its formation. The keynote to their successful action is simply that the deposit is of such a nature that it can be easily wasted or blown out of the boiler.

The practical utility of the alkalies as scale preventatives is admirably stated by J. N. Barr in a paper read before the Northwestern Railway Society on "The Treatment of Waters Used in Locomotives to Prevent Corrosion." The composition of the boiler compound which he has introduced and which is at present in use on the Chicago, Milwaukee & St. Paul Railroad is: 3750 gallons of water, 2600 pounds (70 per cent.) caustic soda, and 1600 pounds (58 per cent.) soda ash. This mixture forms a strong solution of caustic soda and soda ash and costs about four cents per gallon. It is used over the greater part of their system and the results are said to be entirely satisfactory. In order to determine the amount of boiler compound to use, the waters were first subjected to careful analysis, and the amount and nature of the incrusting ingredients ascertained. The next step was to find out how much water each engine was expected to take at the different watering stations. From the analyses of the waters and the amount consumed on the trip, the total weight of incrusting ingredients that would be deposited was made known. It was then found by experiment that one-fourth of the amount of compound, theoretically deduced by analysis, would be amply sufficient both for the gradual removal of the old scale and the total prevention of any new incrustation. The boiler compound is charged in the round house, introducing into the tender the total amount required for the run, even if water is taken at one or more intervening stations. With an engine running on water containing an average of 2.1 pounds of incrusting ingredients per 1000 gallons it is necessary to change the water every 600 miles and wash out the boiler after every 1200 miles. In addition to this the engineer uses the blow-off cock when the water gives any decided indication of priming. The article closes with numerous testimonials from the engineers which speak in very flattering terms of the efficiency of the compound.

ALBAN EAVENSON, '91.

(To be continued.)

THE MANUFACTURE OF HEAVY ORDNANCE AND ARMOR PLATE.

Until the year 1888 the United States was entirely dependent upon foreign manufacturers for the heavier types of modern guns, and for armor plate capable of affording a protection against such heavy ordnance, but from that year to the present time the government has been on a more independent footing through the establishment of factories in this country which are now able to produce equal, if not superior, war material to any produced abroad. With the gradual increase in knowledge concerning the best methods and material to employ in the production of these large forgings comes the steady improvement in the quality and rapid delivery of the product, and the United States is gradually coming to the front in ordnance matters. It is proposed in this article to give a short description of the manufacture of government war material.

To begin with, open hearth steel is used altogether as gun and plate metal. A rough statement of the manner of producing this steel is as follows: A charge, made up of pig iron, muck bar, scrap, and other materials is melted in a furnace by burning coal gas, and this bath is added to from time to time, the percentage of carbon, by which the proper degree of hardness for the steel is fixed, being gradually lowered. Several of these charges may be made before the addition of the carbonizers, or materials which are to give the heat its final composition. These last consist of spiegel and ferro-manganese. During the heat several tests are taken by which to determine the state of the bath. These are poured in a small mould, hammered out, and broken, when the character of the grain indicates the condition of the fused metal. They are also analyzed for composition. Phosphorus, the *bête noire* of the steelmaker, is kept at as small a percentage as possible, "low phosphorus" ores being used from the start. It should not run over .035 of 1 per cent. This precaution prevents the steel from being *cold-short* or brittle. Sulphur also should not be present in greater quantity than .04 of 1 per cent. in order to avoid a *red-short* steel, or one which is liable to crack or seam during the process of working at a red heat. Gradually the molten metal approaches the desired condition and is finally "tapped" out of the furnace into a large ladle or bucket.

At the works of The Bethlehem Iron Company the next process is fluid compression. The ladle is moved over, and its contents poured into the mould in which the ingot is to be cast. This mould is of iron lined with firebrick. When it is full it is drawn under the hydraulic press. A piston just fitting the iron mould comes down slowly with great pressure, forcing out the gases in the steel and securing the greatest density and closeness of grain possible. After the ingot thus cast is sufficiently cool it is bored through and cut into "blocks" to be used in producing the various gun forgings. Fig. 1 shows an ingot as it will be cut up and bored, ready to go to the press or hammer. The government requires a certain per cent. of the total weight of the ingot to be discarded from both top and bottom (the greater amount from the top), in order to be sure of the absence of pipe and the general good condition of the metal.

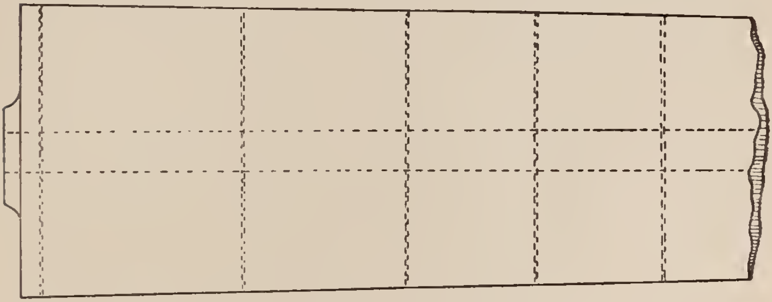


FIG. 1.

That a proper idea may be had of the formation of these large guns, a section of a 12-inch Navy breechloading rifle (Bureau of Ordnance, Navy Department) is given, showing how the various pieces are assembled together and the gun thus "built up" (Fig. 2). This gun and the 12-inch Army rifle are the largest yet tried by the United States. These rifles are about 37 feet long and 12 feet round at the breech. The Army gun weighs 52 tons, and the Navy 45 tons. A 13-inch Navy gun is rapidly being built. The largest gun yet designed by our government is a 16-inch Navy rifle, which is about 49 feet long and weighs 111½ tons, but as yet no order has been issued for this type.

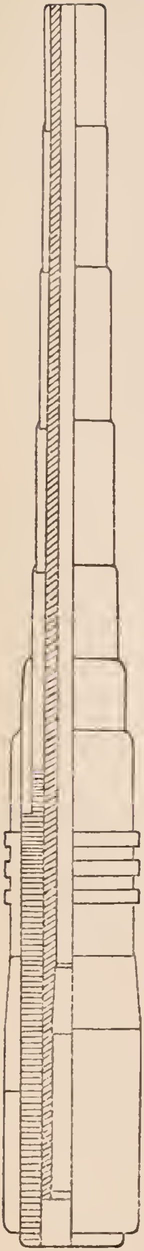


FIG. 2.

The tube, or core, of the 12-inch gun (shown in the figure by oblique section) may be considered the foundation piece. It is this forging that is in actual contact with the gases of the burning powder and the projectile, and which stands the initial pressure of the explosion, being reinforced by the jacket (shown in the figure by vertical section) and heavier hoops on the breech, and by the lighter hoops on the chase of the rifle. When a proper block has been selected from the ingot it is put in a heating furnace and, when at a working heat, is swung under a powerful hydraulic press and drawn on a mandrel to length. At the Bethlehem Works the presses are the Whitworth & Co. (Manchester, England) make. The die, moving slowly and quietly, exerts a pressure of many thousands of pounds, and readily "works" the red-hot metal into the various forgings required—shafts, hoops, tubes, etc. The jacket and hoops are forged in the same way as the tube. The handling of these heavy pieces is successfully accomplished by mechanical contrivances at the press, which, by shifting the heavy chains supporting the forging on the mandrel, cause it to move backward and forward, and turn over and over, the die meanwhile pressing it rapidly into the proper shape.

The press leaves the forgings approximately the shape they are to attain. They are then machined roughly to size and transferred to the tempering plant. The government requires that all its steel material be carefully "treated," that is, tempered and annealed before testing it, to determine its physical qualities. The pieces are lifted out of the heating furnace by an hydraulic crane of probably 100 tons capacity, and plunged into a vat of oil. Oil of low inflammability is used—flashing point 325° to 330° F., burning point 360° F.—and there is a constant circulation about the piece. After tempering the metal in this way it is put in the annealing furnaces, where it is closely surrounded by burning wood. This process draws the temper and relieves strains which may have been caused by the sudden immersion in oil. In treating a piece the heat may be indicated by its color, a blood red, for instance, corresponding to about 1100° F., salmon to 1500° F., and yellow, or about forging heat, to 2100° F. In the manufacture of gun forgings for the Navy the last process must be an annealing one.

After treatment the forgings are taken to the machine shop and test pieces slotted out and turned up into a test bar or "specimen." Fig. 3 shows an army test specimen three inches long between measuring points. This specimen is commonly cut from tubes and jackets, and is representative of the usual specimens taken by the government. At the Bethlehem Works an Emery testing machine is used. The specimen is carefully measured between the points as marked. It is then subjected to stress to determine its elastic limit, or the load it will bear before taking a permanent "set." The load is then increased to determine its ultimate strength, and after fracture the extension of the bar during stress, the reduction of area at the break, and the appearance of the fracture are carefully noted. These specimens, taken from both ends of the principal pieces, indicate the character of the metal with fair accuracy. By a comparison of from three to six specimens from an end of a forging a good idea may be had of

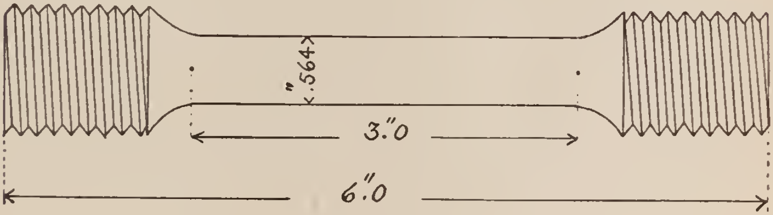


FIG. 3.

the uniformity of the piece. The bars are somewhat small, and for fine experimental work would not be as good as a large specimen 8 inches between points by 1 inch in diameter, but with an electric micrometer attachment the determinations of the elastic limit of the smaller bars may be made with such accuracy, and their number affords such a good comparison that the results indicate the quality of metal satisfactorily.

With the acceptance of the piece as to tests the rough forging is ready for shipment after the extra strip of test metal has been cut off. The gun is "built up," or the various parts assembled, at the government factories. In this latter process the forgings are machined with great nicety and according to careful mathematical calculation. The jacket first is bored a shade smaller than the tube, carefully heated until it expands, slipped over the tube into place, and then sprayed until it is firmly shrunk on. The hoops succeed this in overlapping layers and when all are in place the gun is "turned up" on the outside (as shown in the lower half Fig. 2), rifled in the bore, fitted with its rather complicated breech mechanism — too full of detail to discuss here — and stands ready for its first proof round.

In manufacturing armor plates there are a variety of methods in practice by which the makers hope to secure the most effective resistance to the penetration of the projectiles thrown by the heavier types of ordnance, and repeated experiment is gradually pointing out the best. The English manufacturers believe great results can be achieved with "compound" plate, that is, a steel face and a wrought-iron back mechanically welded, the idea being to break up the projectile, or prevent its penetration, with the hard face, and keep the plate from developing serious cracks with the soft backing. Upon being put to an ordinarily severe test this plate has proved inefficient, large pieces of the hard front breaking loose, and the plate cracking badly. The French all-steel and nickel-steel plates show excellent ballistic resistance, having the face hardened by a treatment process. They are superior to the English plates. In the United States the "Harvey" process of supercarburization or cementation has been used with seeming success. In this process the plate is buried in sand in a furnace with the exception of one face, on which a quantity of carbonaceous material is placed, this in turn being covered with sand and brick. The mass is then kept at a high heat for a certain length of time and allowed to cool slowly. A portion of the carbon is "absorbed," which renders the face of the plate much harder. Just how deep this hard surface extends, under certain conditions of heat and length of exposure, has not as yet been accurately determined. This government has the right of use of this process.

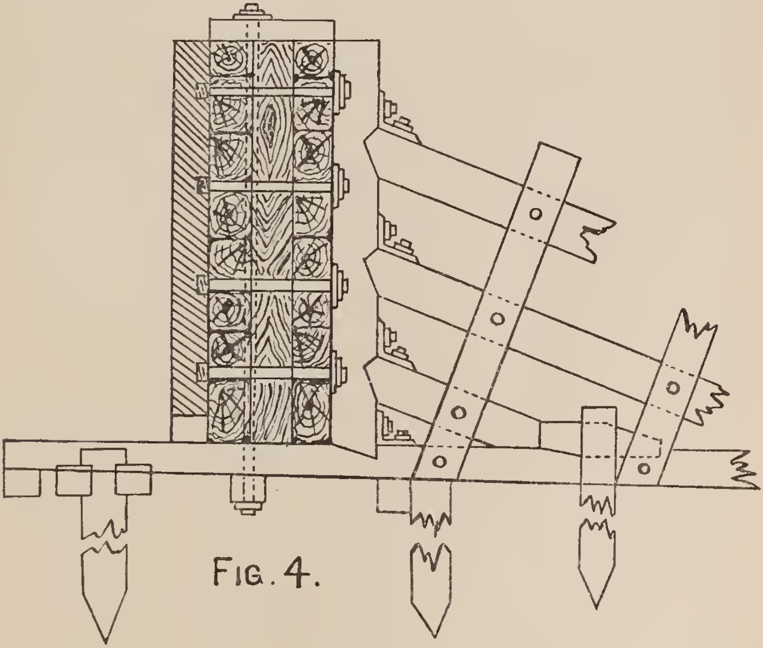


FIG. 4.

At present there are but two firms in the United States which manufacture heavy armor plate, viz., Carnegie, Phipps & Co., of Pittsburg, Pa., and The Bethlehem Iron Company, of South Bethlehem, Pa. The former *roll* the plates and the latter *forge* them under a steam hammer. The production of the ingots from which the plates for the United States Navy are made at Bethlehem differs from those of which gun forgings are made by the addition of nickel to the heat, which has been proved to increase the value of a steel plate, in that it gives it a higher tensile strength and

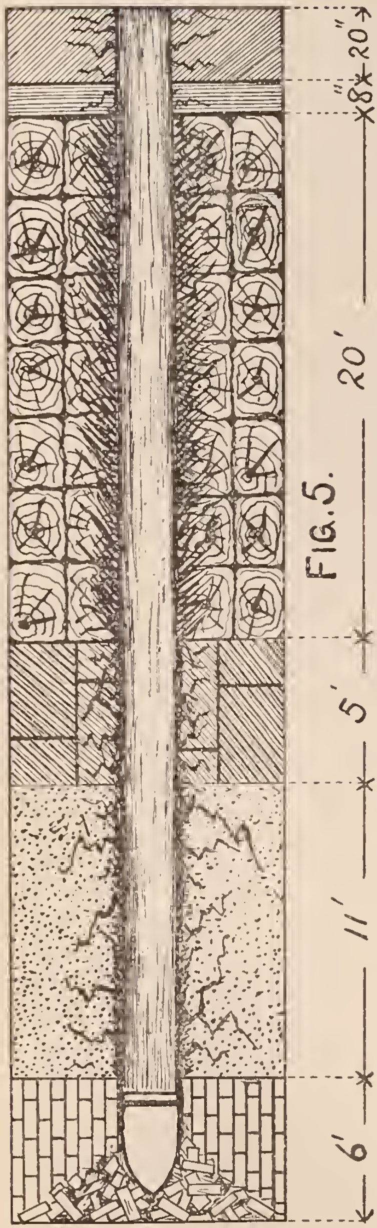


Fig. 5.

renders it less liable to crack on ballistic impact. Under the steel-faced tap of Bethlehem's 125-ton hammer the ingots rapidly take the shape of plating for the armament of the new ships of war.

The acceptance of armor plates depends on the result of the ballistic test of a plate selected out of a group which has been made up of a number of plates from which *tensile tests* have been taken. The plates are grouped according to the grade which these tensile tests establish. The ballistic test is probably the most severe test the government imposes. Three shots are fired at a plate from a 6-inch or 8-inch rifle, the three points impact being arranged so as to form an equilateral triangle. No projectile or fragment of the plate must get clear through the plate and backing. No large cracks which expose the backing must appear before the impact of the third shot, and the plate must not break up and pieces be detached before the impact of the third shot. Provision is made for the test of plates in very cold weather by allowing a test-plate to be warmed to not above 60° F. if the temperature is 40° F. The velocity of the projectile which is fired at the plate must have sufficient energy to just pass through a *wrought-iron* plate and its backing of 36 inches of wood, it being supposed that the wrought-iron plate is of the same thickness as the test plate. This velocity is calculated by the formula of Gavre, viz.:

$$\frac{pV^2}{a} = 3507\,E^2 + 22654642e^{0.25}$$

in which $p =$ weight of projectile in pounds.
$a =$ diameter of projectile in inches.
$V =$ velocity at impact in feet per second.
$E =$ thickness of backing in inches.
$e =$ thickness of armor plate in inches.

A formula deduced for *steel* plates and in use at one of the large ordnance works in France is

$$\log E^{0.7} = (\bar{4}.99066) + \log\left(\frac{p^{0.5}\,v}{a^{0.75}}\right)$$

in which p, a, and v are the same as in the Gavre formula, and $E =$ the thickness of plate in inches.

There have been several competitive tests of armor plate both in this country and abroad, and in the last year or two American plate has been acknowledged to hold a high place. Fig. 4 shows the method of attaching the plate to its backing for a trial. The plates tested thus far have withstood the attack of 6-inch and 8 inch guns effectively. What the heavier calibres would do with them has not been demonstrated as yet by practical test in this country. Some idea of the power of the larger guns may be had by a glance at Fig. 5. The illustration is taken from an account of an exhibit made by the Armstrong-Mitchell Company at the Naval Exposition in London, as given in *Engineering* (English). The gun was an 110-ton rifle, of which full charge is 960 pounds of brown prismatic powder and projectile weighs 1800 pounds. The life of one of these guns is about 75 rounds (full charge) In this case the muzzle velocity was 2105 feet per second, and the total energy 55,305 foot tons. The illustration is a graphic delineation of the power of this rifle. The shot first met a 20-inch compound armor plate, then an iron plate eight inches thick. Beyond these was a built up structure of twenty feet of solid oak balks, then five feet of granite, and back of this eleven feet of concrete. Finally came six feet of brickwork. The shot struck fairly in the centre of the plate, traveling with a velocity of 2105 feet. It went through plates, oak, granite, concrete, and was finally brought up by the bricks, although it forced out a large wedge of brickwork and nearly got through.

RALF R. HILLMAN, '91.

THE DURHAM MINES.

These mines and the furnace are situated about a mile and a half southwest of Riegelsville, on the Delaware River, in Bucks County. They are about ten miles from Bethlehem across the hills by the way of Hellertown. The roads are generally good and walking is one of the best ways of getting to the mines.

The furnace and entrance to one mine are in a small hollow or valley that opens upon the Delaware. The valley is a sort of saddle of limestone between parallel ridges of gneiss. A series of these ridges of archaen rock, running nearly parallel to South Mountain, can be seen, intersected by the Delaware River, all along between Easton and Durham Furnace. South Mountain is itself a good example of one of these ridges of gneiss and it is in this gneiss that the magnetite of this region is found. About a mile and a half below Durham Furnace the river cuts into the red shales and sandstone of the Mesozoic rock, which forms a bluff a couple of hundred feet high along the west bank of the river.

The Durham furnace and mines are among the oldest in the state. The furnace is run according to modern ideas, but the facilities for transportation are not good, as all iron ore or coal that is to be shipped by railroad must be ferried across the river.

The entrance to the first mine visited, the Rattlesnake, is about three hundred yards up the hollow from the furnace, and the superintendent kindly had one of the company locomotives take our party there.

On the way up one of the men pointed out to us the summer home of Mr. Raymond, the noted mining engineer and secretary of the Institute of Mining Engineers.

The mine is entered by a tunnel that goes directly into the hill.

After getting candles and putting on some miners' clothes the party crowded into two small mine cars and we began our journey into the mine, a mule drawing our train.

The roof is so low in places that it was dangerous to get the head much higher than the sides of the car. The tunnel, which seemed very crooked at first, has a general direction about parallel to the strike of the bed, *i. e.*, N. 17° E., and goes through the barren rock of the hill for about five hundred feet before it strikes the north edge of the bed, along the strike of which it follows to its south limit, over a thousand feet in all.

The deposit is a magnetite and occurs in two parallel beds with nearly one hundred and seventy-five feet of rock between. The upper and east bed is poor and has not been much worked. The beds are in the gneiss of the hill before mentioned and outcrop at the top where they were once worked. The dip of the beds is about 33° south-east.

The present working, which begins at the south limit, extends only about five hundred feet along the strike of the bed, at which point there is an extensive roll that changes the dip toward the north.

The beds average about eight feet in thickness and numerous horses of rock are found, but there is always a leader that can be easily followed and always opens up again to the full width of the bed. The superintendent of the mine told us that where the ore contained mica it generally became poor, but where much quartz was found the opposite occurred.

Thirty or forty years ago the deposit was worked from the base of the hill, along the bed to near where the tunnel meets it, and at this point they lost the seam. Afterwards it was mined at the outcrop on the hill top by a slope, till the cost of raising the water, of haulage, and the poor ventilation caused them to seek some other means of attacking the deposit. The tunnel was then driven from the base of hill to meet the bed and then along the strike, passing about forty-five feet below the foot of the old slope.

METHOD OF MINING.

After the tunnel had been driven and the ore taken out between the tunnel and the lowest level of the old working above, leaving a pillar of ore to support the slope, the slope was continued down the tunnel level. Hoisting engines were put in the old slope and are driven by air furnished from a compressor at the tunnel mouth. Next the slope was driven down the bed fifty feet farther, and at the bottom levels or gangways were driven to the right and left of the slope along the strike of the bed. As soon as these were driven far enough from the slope not to interfere with its working, they began to work the ore up toward the tunnel or level above. As the miners blast out the ore, the poor ore and rock of the bed, called gob, is piled behind them, leaving a way through the gob by which to slide down the ore to the gangway below. The passages are called shutes and are timbered when necessary. (See Fig. 1.)

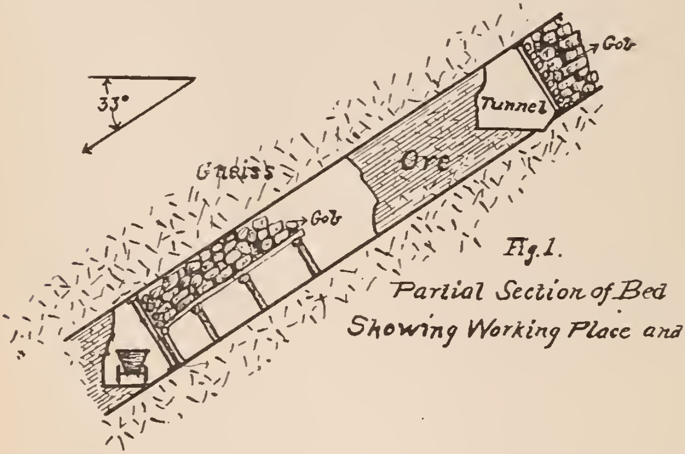


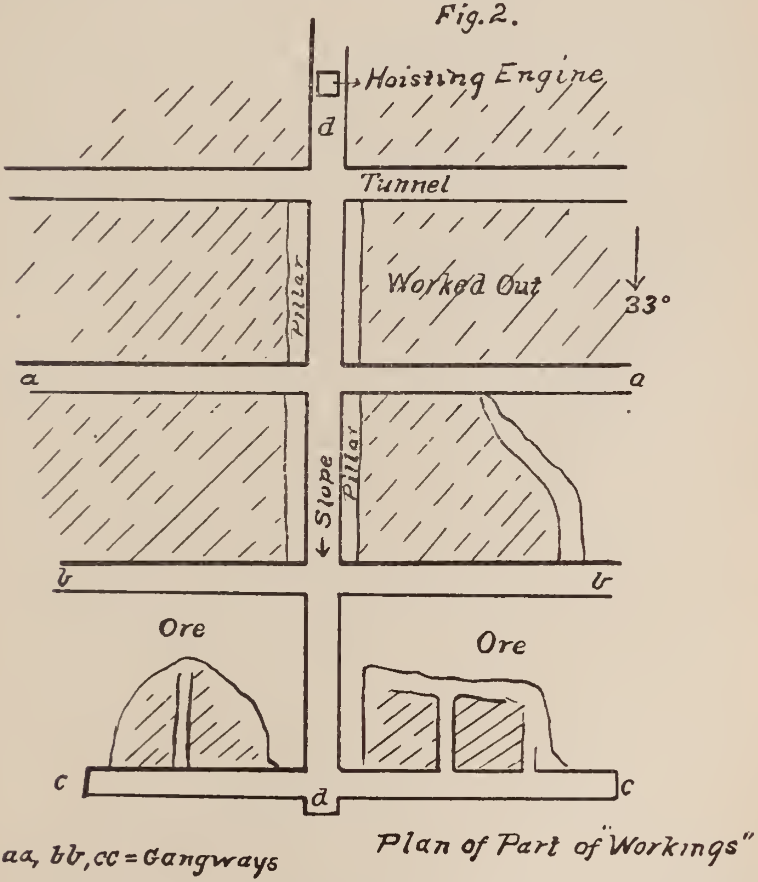
Fig. 1.
Partial Section of Bed
Showing Working Place and Shute

There is generally enough poor ore and rock in the deposit to fill the worked-out places, but where there is not, rock is obtained from some other place or the roof allowed to cave.

As the men work from one level toward the next above and the ore between them is taken out, the whole space is filled in with this loose rock or gob, only leaving the shutes through it. The upper side of the gangways are timbered to keep the gob from coming down into them and blocking the tracks. As the ore is mined it is sent down the shutes to the level or gangway below where it is loaded in small cars, carried along the level to slope, and there dumped in the skips that carry it up the tunnel level and dump it into an ore-pocket. From this pocket the ore is run into the cars and drawn by a mule out the tunnel to the surface.

The skips are small iron cars, only open at the front end, and are drawn up the slope by the hoisting engines.

Fig. 2.



Plan of Part of "Workings"

The gangways are driven about two hundred and fifty feet on each side of the slope, and when all the ore has been taken out between one level (gangway) and the one above, and the worked-out places packed with gob, the slope is continued down fifty feet farther, new levels driven, and the same operations again gone through.

A pillar of ore is always left along the slope to protect it. The lowest level is now about one hundred and fifty-feet below the tunnel (see Fig. 2). Where cross-sectioned, it denotes that the ore has been taken out at that place and has been filled in with the loose rock.

All drilling in this mine is done by round drills driven by compressed air. There is also a pump at the foot of the slope, and this, too, is run by compressed air. The water is forced from the bottom of the slope to the tunnel level, out of which it runs by gravity.

The ventilation is through the old workings, and is caused by the difference in elevation of the two openings; namely, the head of slope on the top of the hill and the mouth of the tunnel.

The men work by candlelight and carry their candle in a ball of putty which they can stick on a rock or timber.

The only means of getting from one level to another is by ladders. After climbing over these for about two hours we came back to the tunnel and found our mule-train waiting for us.

The next mine visited is about a mile southwest of Rattlesnake Mine. On our way there our guide, the mine superintendent, showed us the outcrop of the bed of the Rattlesnake Mine and the old workings on top of the hill. He also pointed out to us a field where the Indians of the neighborhood are said to have raised their corn, also a quarry where the red jasper was obtained from which the red jasper arrow-heads of the region were made.

The deposit of the second mine visited seems to be a mass deposit and is a hematite instead of a magnetite, as is found at the Rattlesnake Mine. It consists of two parallel bodies of ore, with a dip of about 35° at top, but appears to flatten out as it is worked deeper. One deposit is directly over the other with generally ten to twenty feet of rock between. Along the strike, which is north and south, the body of ore measures only about eighty feet and each deposit has an average thickness of twenty-five feet. In this mine no horses of rock are found.

The ore was first mined from the outcrop by a slope, but is now reached by a tunnel driven from the surface on the hillside, the slope and old workings only being kept open for the sake of ventilation. The tunnel is over thirteen hundred feet long and so straight that any one can easily see the entrance from its farthest end.

METHOD OF MINING.

When the tunnel was driven, it struck the upper part of the lower body of ore and then a winze was driven up through the roof of the tunnel to the bed above. Also a cross-cut is being driven, at right angle to the tunnel, through the rock, to connect with the upper bed at the elevation of the tunnel. From the point where the winze meets the upper body of ore, a slope was driven up the pitch of the deposit to connect with the old slope, and at certain distances (about fifty feet) levels were driven across the deposit parallel to the strike. Then narrow breasts were driven, connecting the levels and cross headings connecting the breast, thus dividing the ore to be worked into a number of small blocks. The uppermost block nearest the old workings is first mined out, and the ore slid down the breast to the level below. It is wheeled from there to the slope and then down the slope to the winze, through which it passes into the cars below in the tunnel. As the work goes on the roof is allowed to cave in as the men work back toward the winze. In this method they begin at the top and work down, while in the Rattlesnake they work from one level toward the next above it.

Most of the drilling in this mine is done by hand, as the compressor they have is not large enough to do the work. No pumping is needed, as the mouth of the tunnel is lower than any of the present workings. The lower body of ore has not been worked much down near the tunnel, but will be as the mine is extended.

HEBER DENMAN, '92.

THE THEORY OF CENTRIFUGAL VENTILATING FANS.*

Determination of their Forces and Dimensions.

BY LOUIS SER.

TRANSLATED BY JOHN T. HOOVER.

III. DETERMINATION OF THE DIMENSIONS OF A VENTILATOR.

When we study in a general manner the problem of the determination of the dimensions of a ventilator, we see that the equations previously established furnish fifteen different relations between twenty-six quantities, volume, velocity, pressure, and dimensions of the ventilator. In general, seven of the quantities are known *à priori*, or are determined directly from the known elements of the problem. It is sufficient, then, to chose properly the angles β, θ, and γ, and also the angular velocity ω, in order to solve the problem.

Instead of having given the angle γ, we may have the condition that the jaws of the ventilator be plane and parallel, that is $b_1 = b_0$. This is a case which we shall examine especially.

To calculate the principal dimensions of the ventilator one can proceed in the following manner:

25. INTERIOR RADIUS OF VANES.—The radius of the vanes is deduced immediately from equations (44), giving

$$R_0 = \sqrt[3]{\frac{Q}{\phi\omega}} \qquad (56)$$

The value of ϕ depends (43) on that of the angles β and θ, and on the ratio $\frac{R}{R_0} = \mu$. Taking $\theta = 90°$ and $\mu = 0.75$, we have in the limits the probable values of β:

For $\beta = 30°$, $\sqrt[3]{\frac{1}{\phi}} = 0.788$

" $\beta = 45°$, " $= 0.737$

" $\beta = 60°$, " $= 0.657$

These values, as we see, differ little from each other. Experience only can make known the values of β and ϕ which serve best each case. We can take, as a value at least approaching the mean, $\sqrt[3]{\frac{1}{\phi}} = 0.737$, which gives:

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*Begun in Vol. I, No. 4.

$$R_o = 0.737 \sqrt[3]{\frac{Q}{\omega}} \tag{57}$$

This formula applies only for $\theta = 90°$. If this angle were different, the coëfficient would be greatly changed. So for $\theta = 25°$, $\mu = 0.75$, and $\beta = 45°$ we find

$$\mathrm{R}_o = 1.1 \sqrt[3]{\frac{Q}{\omega}}.$$

26. RADIUS OF THE INLET.—The radius of the inlet is deduced directly from R_o by the relation $R = \mu R_o$. We have taken $\mu = 0.75$. By the aid of a diagram we can ascertain if, with this ratio, the joint of the inlet with the origin of the vanes makes the best conditions.

27. EXTERIOR RADIUS OF THE VANES.—The exterior radius of the vanes R_1 is calculated by means of equations (33), which, solved for R_1, gives:

$$R_1 = R_o \frac{\sin\beta \cos\gamma}{2 \sin(\theta + \beta)} + \sqrt{R_o^2 \left[\frac{\sin^2\beta \cos^2\gamma}{4 \sin^2(\theta + \beta)} + \frac{\sin\theta \cos\beta}{\sin(\theta + \beta)}\right] + \frac{gH}{\omega^2 d}}, \tag{58}$$

a formula which applies to all ventilators in which the air enters without shock and the section between the vanes is constant. If $\theta = 90°$, it reduces to

$$R_1 = R_o \frac{\tan\beta \cos\gamma}{2} + \sqrt{R_o^2 \left(1 + \frac{\tan^2\beta \cos^2\gamma}{4} + \frac{gH}{\omega^2 d}\right)}. \tag{59}$$

Finally, if we further make $\gamma = 90°$, that is to say, if the vanes are radial, we have the very simple formula,

$$R_1 = \sqrt{R_o^2 + \frac{gH}{\omega^2 d}} \tag{60}$$

We see that the radius R_1 is always greater than R_o, as it should be, and that it increases with the pressure to be produced. To calculate it we must know the value of H. We may have two cases.

Very often we know *à priori*, the excess of pressure $p^1 - p$, to be be produced between the discharge port and the admission port of the ventilator, either by former experiences, or by comparison with similar works; then we have to employ formula (37): $H(1 - m) = p_a' - p_a + h' - h$.

The velocities v and v' are calculated by equations (3) and (17), and we deduce h and h' by equations (1) and (18). The ratio m is estimated from the efficiency of similar apparatus. Everything being known in the equation, we can then obtain the value of H.

When $p' - p$ is not given *à priori*, we take the second relation of (38): $H(1 - m) = p_a' - p_a + ch + c'h' + h''$. We know $p_a' - p_a$ and h'', we calculate h and h' as above, and c and c' from the length and dimensions of the conduit, we estimate the ratio m, and the equation then furnishes the value of H.

In both cases, H being known, the general equation (58) finds the value of R.

In the particular cases specified, we must employ the more simple relations (59) or (60).

28. WIDTH OF VANES.—The width b_0 of the vanes at the entrance is deduced from equations (7) and (8) combined; we find $2\pi R_0 b_0 v_0 \sin\beta = \pi \mu^2 R_0^2 v_0$, from which

$$b_0 = \frac{\mu^2}{2 \sin\beta} \qquad (61)$$

If we make $\mu = 0.75$ and $\beta = 45°$, we find $b_0 = 0.3987\ R_0$ or $b_0 = 0.4\ R_0$. If $\mu^2 = 0.7$, we have $b_0 = 0.5\ R_0$.

To realize the condition $w_1 = w_0$, that is, to maintain the section constant between the vanes, it is sufficient to change their width according to the distance from the centre of rotation. The width b_1 at the extremity is obtained by combining equations (8) and (4):

$$2\pi R_0 b_0 v_0 \sin\beta = 2\pi R_1 w_1 b_1 \sin\gamma;\ \text{then 10:}$$

$v_0 = \omega R_0 \frac{\sin\theta}{\sin(\theta+\beta)}$ and (11) and (24): $w_1 = w_0 = \omega R_0 \frac{\sin\beta}{\sin(\theta+\beta)}$;

substituting $R_0 b_0 \sin\theta = R_1 b_1 \sin\gamma$, whence

$$b_1 = b_0 \frac{R_0 \sin\theta}{R_1 \sin\gamma}. \qquad (62)$$

In general, calling x the width at a distance y from the axis, the curve of the wings making at this point an angle α with the circumference, we have

$$x = b_0 \frac{\sin \theta}{y \sin \alpha}, \tag{63}$$

the equation of a hyperbola when the angle α is constant; thus the vanes ought to have laterally a hyperbolic form. Generally the portion of the hyperbola used is approximately a right line, and the surface of the vanes is a trapezium of which the sides are b_0 and b_1 and their distance $R_1 - R_0$.

For a ventilator with radial vanes, $\theta = 90°$, $\gamma = 90°$, we have

$$b_1 = b_0 \frac{R_0}{R_1} \tag{64}$$

and in general, at a distance y from axis,

$$x = b_0 \frac{R_0}{y}. \tag{65}$$

29 VELOCITIES AND PRESSURE.—The velocities and pressures in the different sections of the circulation are deduced immediately from one of the equations established in the general theory:

v and v' are given by equations (3) and (17),
v_0 by equation (10),
$w_1 = w_0$ by equation (11),
v_1 by one of the equations (13) or (26).

The differences of pressure are obtained thus:

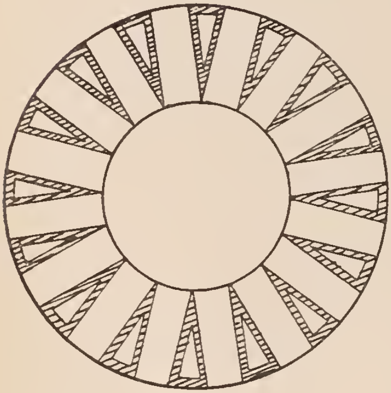
$p_a - p$ by equation (2),
$p - p_0$ by equation (4),
$p_1 + f - p_0$ by equation (36), and as $f = mH$ is known, we have $p_1 - p_0$.
$p' - p_1$ is calculatet by equation (16),
$p' - p''$ is calculated by equation (19),

We can verify by equation (21) the value of $p'' - p_a'$ found.

30. CASE WHERE THE CANALS ARE PLANE AND PARALLEL.—One is led sometimes to make the canals of the ventilator plane and parallel for facility of construction, so that $b_1 = b_0$. We can in this case maintain the section constant between the vanes in several ways.

One of the most simple is shown in Fig. 4; each vane is formed of three sides in triangular shape, forming a closed space in which there is no circulation of air. Making the sides of the changing canals parallel, the section is constant.

Fig. 4

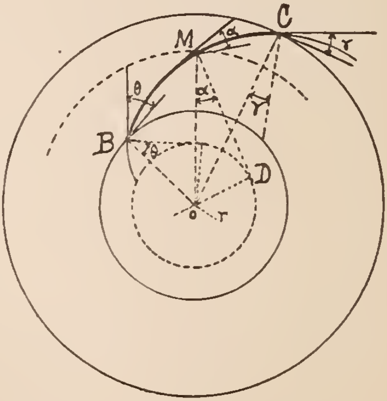


The axis of the canals may be directed radially, or, indeed, to make an angle more or less pronounced, in order to give a determined direction to the velocities of entry or discharge.

By replacing the vane of uniform thickness with one of triangular shape, we change the value of the angles; but the alteration is hardly perceptible if the number of vanes is large enough.

We can still realize simultaneously the two conditions $b_1 = b_0$ and $w_1 = w_0$ by making the vanes arched, following a curve (see Fig. 5) such that the distance between the vanes, measured normally, remains constant from the origin to the exterior circumference.

Fig. 5.



If in equation (62) we make $b_1 = b_0$, then $R_1 \sin \gamma = R_0 \sin \theta$.

Generally, for any point of the curve situated at a distance y from the centre, we find, calling α the angle which a tangent to the curve makes with the normal at oM,

$$y \sin \alpha = R_0 \sin \theta = \text{constant}, \qquad (66)$$

an equation which applies to the development of a circle, of which the radius r of the circle of the base is

$$r = R_o \sin \theta. \tag{67}$$

The calculation of R_1 such as we have given above in SECTION 27, supposes that we know the angle γ. In the case where the vanes are drawn along a development of a circle, this angle is not known; it is given by the relation $\sin \gamma = \frac{R_o}{R_1} \sin \theta$ and depends, as we see, on R_1. To calculate R_1 we must eliminate γ.

Let us consider only the case where $\theta = 90°$; we have then the two equations,

$$H = \omega^2 \frac{d}{g}(R_1^2 - R_o^2 - R_1 R_o \tan \beta \cos \gamma) \quad (34) \text{ and}$$

$$\sin \gamma = \frac{R_o}{R_1}.$$

We get from this last, $\cos \gamma = \pm \sqrt{1 - \frac{R_o^2}{R_1^2}} = \pm \frac{1}{R_1} \sqrt{R_1^2 - R_o^2}$.

Substituting, we have

$$H = \frac{\omega^2 d}{g}(R_1^2 - R_o^2 \pm \tan \beta \sqrt{R_1^2 - R_o^2}), \text{ whence}$$

$$R_1^2 - R_o^2 - R_o \tan \beta \sqrt{R_1^2 - R_o^2} - \frac{gH}{\omega^2 d} = 0, \text{ and}$$

$$\sqrt{R_1^2 - R_o^2} = \frac{R_o \tan \beta}{2} \pm \sqrt{\frac{R_o^2 \tan \beta}{4} + \frac{gH}{\omega^2 d}},$$

$$R_1^2 - R_o^2 = \frac{R_o^2 \tan \beta}{4} + \frac{R_o^2 \tan \beta}{4} + \frac{gH}{\omega_2 d} \pm$$

$$R_o \tan \beta \sqrt{\frac{R_o^2 \tan \beta}{4} + \frac{gH}{\omega^2 d}},$$

and finally,

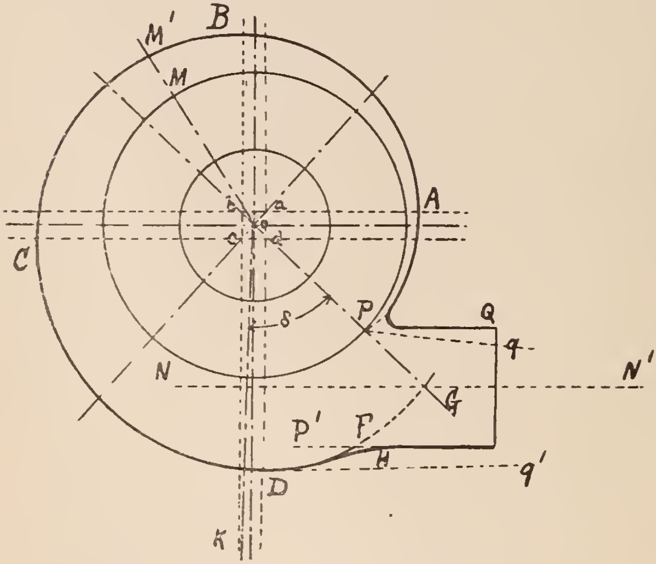
$$R_1^2 = R_o^2\left(1 + \frac{\tan^2 \beta}{2}\right) + \frac{gH}{\omega_2 d} \pm R_c \tan \beta \sqrt{\frac{R_o^2 \tan^2 \beta}{4} + \frac{gH}{\omega^2 d}}. \tag{68}$$

When the ventilator turns so as to push the air with the convexity of the vanes, γ is less than 90° and $\cos \gamma$ is positive. On the contrary, if the vanes push the air with their concavity, γ is greater thad 90° and $\cos \gamma$ is negative.

If $\beta = 45°$, we have $R_1^2 = \frac{3}{2} R_0^2 + \frac{gH}{\omega^2 d} \pm R_0 \sqrt{\frac{R_0^2}{4} + \frac{gH}{\omega^2 d}}$ and the velocity of discharge is, from equation (27), $\beta = 45°$ and $\cos \gamma = \pm \sqrt{R_1^2 - R_0^2}$, $v^2 = \omega^2 (R_0^2 + R_1^2 \mp 2 R_0 \sqrt{R_1^2 - R_0^2})$.

We use the sign ∓ (*minus or plus*) in this formula, as the vanes push the air with their convexity or concavity.

Fig. 6.



31. FORM OF THE ENVELOPE.—The envelope of the ventilator should have a form such that the velocity shall be constant or slightly increasing, and, further, it ought to open into the conduit of compression in a fixed direction.

Let NN' (Fig. 6) be this direction, and δ the angle which the velocity of discharge v_1 makes with the tangent at the exterior circumference. This angle is given by the relation

$$\frac{w_1}{v_1} = \frac{\sin \delta}{\sin \gamma} \qquad (69)$$

To get the point P, the origin of the spiral which should form the envelope, it is enough to produce OK perpendicular to NN', and the ray OP making with OK the angle δ gives the point P.

The section Ω_1 at the entrance to the compression conduit is $\Omega_1 = \frac{Q}{v^1}$.

If the section of the envelope is rectangular and the width E, which is determined from that of the vanes, constant, we find the height, $L = QQ^1$, of the rectangle by the relation, $L = \frac{\Omega_1}{E}$.

In order that the velocity in the envelope may remain constant, the section X, in any point must be

$$X = \Omega_1 \frac{\propto}{2\pi}.$$

$\propto$ being the angle MOP.

When the width of the envelope is constant and equal to E, the height of the spiral measured on the prolonged radius is $MM' = L \frac{\propto}{2\pi}$.

We can thus, by giving to $\propto$ a succession of values, determine as many points as we wish of the curve and can trace it exactly from the point P to the point G, so that $PG = L$.

The trace of the spiral by points can be replaced by that of the volute which is obtained, as we know, by means of four arcs of a circle having for centre successively the corners a, b, c, d of the square of which the side equals $\frac{1}{4} L$.

To end the envelope, we draw PQ and $P'Q'$ parallel to NN' and at a distance $QQ' = L$, which gives the position of the compression conduit. The spiral meets the line $P'Q'$ in a point F and makes with it an angle more or less obtuse. In order to avoid back pressure, it is best to join, by a very long curve, DHQ'. In QQ' is the orifice of discharge from the envelope of which the section is Ω, and in which the pressure is p_1 and the velocity v_1.

We can now determine the envelope by drawing from the points P and D the right lines Pq and Dq', a little inclined to NN', and prolong them until their distance qq', measured normal to NN', is equal to PG or L.

Finally we round off the beveling at P, which would produce a disagreeable noise, by means of a joint properly rounded.

The direction of the velocities at the discharge from the vanes tends to throw the current against the interior sides of the envelope, which ought to generate a motion of the fluid filament coming from the anterior parts of the circumference. For this reason it would be more advantageous to give to the spiral a form a little more eccentric which would increase slightly the section, would gradually reduce the velocity and would, in a certain case, facilitate the joining with the compression conduit.

This increase of section could also be obtained by a gradual increase in width of the envelope, so as to terminate regularly in a square or round orifice. It is for experience to speak on this subject.

The joint with the conduit should be made with a very long truncated conical pipe to avoid back pressure. The angle of the cone should be that which gives to the fluid vane the form of expansion which it tends to take normally; that angle seems to be about 8°, corresponding to an inclination of $\frac{1}{7}$ to the metre.

From this, to pass from the section Ω_1 of the compression conduit, we must have a space l between the two sections given by the relation $D' = D_1 + \frac{1}{7}\,l$, D' and D_1 being diameters or sides of squares corresponding to Ω' and Ω_1. Whence, $l = 7\,(D' - D^1)$.

32. Application.—Let us apply the preceding formulæ to calculate the dimensions of a ventilator under the following conditions:

The ventilator must inhale in one second a volume of 10 cubic metres of air at 15° through a conduit two metres in diameter and 45 metres long, and discharge it into another of one metre diameter and 57.5 metres long, terminated by one or more openings through which the air must escape with a velocity of 24 metres.

The difference of the extreme pressures, $p_a{}^1 - p_a$, between the room where the ventilator discharges and that where it exhausts is 0.02 metre.

First we calculate H. Let us use the relation

$$H(1 - m) = p_a{}^1 - p_a + ch + c'h' + h''.$$

We find successively

$$\Omega = 3.1419\ mq.;\ v = 3.1828\ m.;\ h = 0.0006331;$$
$$\Omega = 0.7850\ mq.;\ v' = 12.73885\ m.;\ h' = 0.0101424;$$
$$v'' = 24\ m.;\ h'' = 0.0360000.$$

To calculate the resistances, let us take $K = 0.01$ as the coefficient of friction applying to a conduit of which the sides are rather rough.

$$c = \frac{4KL}{D} = 0.9;\ ch = 0.0005697;$$

$$c' = \frac{4KL'}{D'} = 2.3;\ c'h' = 0.033275.$$

Substituting in this we get $H(1 - m) = 0.0798972$, or in round numbers, $H(1 - m) = 0.8$, which comes by calling $p_a^{1} - p_a = 0.0201028$.

Calling $m = 0.2$, we have $f = 0.02$ and $H = 0.1$.

For difference of pressure at different points,

$$p_a - p = (c + 1)\,h = 0.0012027,$$
$$p' - p'' = c'h' = 0.0233275,$$
$$p'' - p_a' = h'' - h' = 0.0258576,$$

and as $p'_a - p_a = 0.201028$, we have by adding the four equations,

$$p' - p = 0.0704906.$$

This is the difference of pressure between the orifice of discharge and of entry of the ventilator, properly speaking.

As a verification we have

$$p' + f - p + h' - h = H = 0.1.$$

All these elements are applied in constructing a ventilator, whatever may be the velocity of rotation which we give to it.

Let us calculate the dimensions of the ventilator for an angular velocity of $\omega = 50$, corresponding at 475 or 480 revolutions per minute. We find successively by formulæ of Section 25 and following sections:

The interior radius R_0 of the vanes (57),

$$R_0 = 0.737 \sqrt[3]{\frac{Q}{\omega}} = 0.431\ m.$$

The radius R of the inlet,

$$R = 0.75\ R_0 = 0.323\ m.$$

The exterior radius R_1 (60),

$$R_1 = \sqrt{R_0^2 + \frac{gH}{\omega^2 d}} = 0.711\ m.$$

The width b_0 of the vanes at the entrance (61),

$$b_0 = 0.4\ R_0 = 0.172\ m.;$$

The width b_1 at the discharge (64),

$$b_1 = b_0 \frac{R_0}{R_1} = 0.104\ m.$$

We deduce the following from the preceding numbers or from the formulæ of SECTION 13 and following sections:

Velocity at interior edge of vanes,

$$\omega R_0 = 21.55\ m.$$

Velocity at extremity of vanes,

$$\omega R_1 = 35.55\ m.;$$

Velocity of entrance v_0 into eye,

$$v_0 = \frac{\omega\ R_0}{0.7071} = 30.47\ m.$$

Relative velocity,

$$w_0 = w_1 = \omega R_0 = 21.55\ m.$$

Velocity of discharge, v_1,

$$v_1 = \omega \sqrt{R_0^2 + R_1^2} = 41.58\ m.,$$

whence we deduce the section of discharge,

$$\Omega_1 = \frac{Q}{v_0} = 0.2405\ mq.$$

which corresponds to a diameter $D_1 = 0.5532\ m.$

The distance b between the two Ω_1 and Ω^1 is

$$l = 7\,(D^1 - D_1) = 3.1276\ m.$$

Finally we find for the pressure by means of formulæ of SECTION 20 and following sections:

Decrease of pressure in the inlet,

$$p - p_o = \frac{d}{2g}\,(v_0^2 - v^2) = 0.057416.$$

Difference between envelope and inlet,

$$p_1 + f - p_0 = 0.05$$

and as $f = 0.2\ H = 0.02$, $p_1 - p_0 = 0.03$.

Increase of pressure after the envelope,

$$p^1 - p_1 = \frac{d}{2g}(v_1^2 - v^2) = 0.097906,$$

from which, adding algebraically, we get

$$p_1 - p = 0.070049.$$

If we add to this value of $(p^1 - p)$ the loss of force $f = 0.02$ *m.*, and the difference $(h^1 - h = 0.00951)$, we have as proof,

$$H = p^1 - p + f + h^1 - h = 0.1 \ m.$$

It would probably be advantageous, as we have already said, in order to facilitate the motion of the air in the envelope, to have the widening of the spiral begin at its origin. By taking, for reasons shown above, the regular increase of $\frac{1}{7}$ per metre of development, we find that the height of the nozzle at the discharge would be increased by $\frac{1}{7} \times 0.711 \times 6.28 = 0.637$. The total height would be $L = 0.553 + 0.637 = 1.29$. The width would give us with the same expansion, $E = 0.104 + 0.637 = 0.741$, which would give a section, $\Omega_1 = 0.95589$, greater than the section of the compression conduit, which is equal to 0.785.

By reducing a little the expansion of the spiral, we would easily make an exact fit of the envelope to the compression conduit.

The same calculations for angular velocities of $\omega = 10$ and $\omega = 100$ corresponding to the number of revolutions 95.5 and 955 per minute give the results which are united to the preceding in the following table. We can thus show the influence of the velocity of revolution on the dimensions of a ventilator to be constructed and can compare the velocities and intermediate pressures.

Result of calculation of elements of ventilators capable of furnishing for different angular velocities a volume of air $Q = 10$ mc with a pressure $H = 0.1$ m.

Angular velocities: $\omega = 10$ *m.*, $\omega = 50$ *m.*, $\omega = 100$ *m.*

No. of revolutions per minute: $N = 95.5$ *t.*, $N = 477.5$ *t*, $N = 955$ *t.*

Dimensions.

R_0	0.737 *m.*	0.431 *m.*	0.342 *m.*
R	0.553 "	0.423 "	0.256 "
R_1	2.923 "	0.711 "	0.444 "
b_0	0.295 "	0.172 "	0.137 "

	Dimensions.		
b_1	0.074 *m.*	0.104 *m.*	0.105 *m.*
Ω_1	0.332 *mq.*	0.2405 *mq.*	0.1784 *mq.*
D_1	0.650 *m.*	0.553 *m.*	0.476 *m.*
	Velocities.		
v	3.183 *m.*	3.183 *m.*	3.183 *m.*
v_0	10.423 "	30.477 "	48.360 "
$w_0 = w_1$	7.370 "	21.550 "	34.200 "
v_1	30.143 "	41.578 "	56.028 "
v^1	12.739 "	12.739 "	12.739 "
ωR_0	7.370 "	21.550 "	34.200 "
ωR_1	29.230 "	35.550 "	44.380 "
$\frac{v_1}{\omega R_1}$	1.031 "	1.169 "	1.262 "
	Pressures.		
$h^1 - h$	0.00951 *m.*	0.00951 *m.*	0.00951 *m.*
$p_a - p$	0.00120 "	0.00120 "	0.00120 "
$p - p_0$	0.00616 "	0.05742 "	0.14557 "
$p_1 - p_0$	0.03000 "	0.03000 "	0.03000 "
$p^1 - p_0$	0.04665 "	0.09791 "	0.18606 "
$p_1 - p$	0.07049 "	0.07049 "	0.07049 "
$p' - p''$	0.02333 "	0.02333 "	0.02333 "
$p'' - p_a$	0.02586 "	0.02586 "	0.02586 "
	Verifications.		
$H = p' + f - p + h' - h$	0.10000 *m.*	0.10000 *m.*	0.10000 *m.*

An examination of the figures in the table shows that for the same volume and the same total pressure the dimensions differ greatly according to the velocity of rotation, and, naturally, the radii of the vanes are greater as the angular velocity is smaller.

We know also that for the same pressures of entrance p and of discharge p', the intermediate pressures of p_0 and p_1 are very different. This is shown by the diagram of Fig. 7, which shows for the three angular velocities considered the variations of pressure in the circulation for corresponding ventilators.

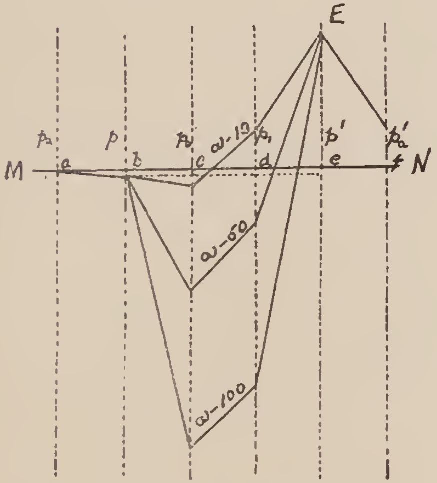
The line MN represents the pressure at the origin p_a; it is parallel to the axis of abscissas which, on account of the scale adopted, can not be shown on the figure (for the normal pressure

$p_a = 10.334$, this axis would be placed at 2.58 *m.* below *MN*.). We have taken at equal distance points, *a b c d e f* and on the corresponding ordinate have laid off, starting at *MN*, lengths proportional to the differences of pressure, $p - p_a$. $p_0 - p_a$, $p_1 - p_a$, etc., above or below *MN* as they are + or —.

Fig. 7.

Diagram of the Variations in pressure.

Scale 1/4 Larger.



Joining all the joints thus determined by right lines, we have a broken line which represents the variations of pressure in the circulation.

The broken line *a b c d e f* corresponds to an angular velocity $\omega = 50$; the two others respectively to angular velocities $\omega = 10$ and $\omega = 100$.

We see that the variations of pressure are greater as the velocity of rotation is greater.

This example suffices to show the course to be followed for the calculations for a ventilator in any case.

PROCEEDINGS OF THE ENGINEERING SOCIETY OF LEHIGH UNIVERSITY.

Regular monthly meeting called to order 7.30 P.M., February 26. President Coleman in the chair and 19 members present. Minutes of last meeting read and accepted. Mr. A. S. Maurice, of the Banquet Committee, reported. Trip of inspection was discussed. Paper on Gas Holders was read by Mr. Rathbun, followed by a discussion. On motion a committee was appointed, consisting of Mr. W. R. Davis, Mr. Bray, and Mr. McKenzie. Mr. A. S. Maurice exhibited a model of Hawkesbury Bridge caisson. On motion meeting adjourned.

Gymnasium, March 24, 1892. Regular monthly meeting. Meeting called to order at 7.30. President Coleman in the chair, 28 members present. Minutes of the last meeting were read and accepted. The following trips were arranged: Visit to Egypt Cement Works, March 25, and visit to Chapman Quarries, April 9. Lecture by Mr. John W. Eckert postponed. Time of next monthly meeting placed at April 21. Mr. McCaskey discussed the method of stripping anthracite coal. The Committee on Rail Bending reported. Mr. Coleman exhibited some mineral wood and discussed its qualities. The president also made some experiments on wooden beams, showing that time was an important factor for rupture. Meeting adjourned.

March 25, 1892. Trip of Inspection to Egypt Cement Works; 32 members made up the party. The party was met by Mr. Eckert, who thoroughly explained their method of making cement.

EDITORIALS.

THIS number of THE QUARTERLY should be especially interesting to the student body, both because of the excellence of the articles and by reason of its being essentially a Lehigh number.

WE are glad to see that an interest in this youthful journal is being manifested by the alumni. They are beginning to display their generosity of spirit, and their affection for their Alma Mater, by contributing exceedingly interesting articles for the edification of the undergraduates, and all other subscribers. Our grateful acknowledgments are extended to all who have contributed to render our tasks in this work easier and more agreeable.

AFTER the next issue, the control of THE QUARTERLY passes on to other hands. Who the editors will be for next year can not, at present, be told, for no election has as yet been held.

But whoever they are, theirs will be the duty of taking up the work where we have left it, and of seeking in every way to make such improvement as will tend to elevate THE QUARTERLY to the very highest standard of excellence.

They will find many of the difficulties removed which at first beset us, and the obstacles which they must themselves encounter can only be entirely removed by the hearty coöperation of our alumni.

STUDENTS are proverbially thoughtless fellows, and frequently commit, in their hours of idleness, little indiscretions which may pardonably be passed over without severe criticism. The time honored custom of "collecting" signs, for instance, has always been considered by the Freshmen, and by even wiser men than they, as an inordinately delightful pastime, while the shopkeepers, poor men, have, not without reason, looked upon it as the most pernicious practice ever indulged in. This and similar indiscretions we term "acts of thoughtlessness," believing that the offenders have made reparation for the damage "in the morning."

But there are other deeds of a far more serious character committed, especially at the time of a class supper, by rattle-pated fellows. Such deeds might becomingly bear the name of "vandalism," and can not be too severely censured. We refer to a circumstance which happened last Winter, when a party of students were returning from a class banquet. The signaling lanterns of the Lehigh Valley Railroad were tampered with and misplaced, and might have been the cause of a more serious accident than that of inconveniencing a signalman. Such pranks, having nothing to recommend them, should be discontinued in future.

THE appointments for Commencement have at last been made, and with what a comfortable sense of relief must the Faculty now be blessed, since they have procured such enthusiastic speakers to officiate on that august occasion.

Graduation Day is undoubtedly the most notable, the most interesting, and the most significant day in the whole four years of a class' career, and the feature of greatest importance on that day, next to the distribution of diplomas and prizes, is the delivery of the speeches. That these should be such as to reflect credit upon the University and also to redound to the glory of the class is apparent to all, and we are sure, in this case, that the gentlemen appointed as the prospective speakers will make an effort to exceed our present anticipations.

However great the success which will this time result from the Faculty's choice of orators, we will venture on a few remarks about the methods of making such appointments in future.

There was a difficulty in obtaining men to speak, and there is no reason why the same difficulty will not always exist. The class is the interested party, or would be, had it any voice in choosing by whom it should be publicly represented on the speaker's rostrum.

As it is, the method of appointment now in vogue is to choose the men of best standing in the different courses, the salutatorian being usually taken from the Classicals. This method is faulty in many respects—not theoretically, perhaps, but, at least, it is so practically. In the first place, there is no sufficient reason why "first standing" men should be good orators; on the contrary, they usually are not, and being conscious of their own inability they politely urge it as an excuse for their non-acceptance of the Faculty's invitation. This necessitates the asking of some one else to take the first man's place. The second choice, if he has an overamount of pride, likewise refuses, and so the invitation passes on from man to man until one is found who is satisfied with his own powers.

In the second place, the class might assist in the election of its speakers, for we know ourselves and each other's accomplishments better than the Faculty possibly can, and would be more apt to choose representative orators, who would not refuse to act.

So long as the custom is a success, it will be well to continue it, but abandon it altogether rather than it should become a fiasco, and than it should lose its interest.

WAIFS AND STRAYS.

"THE dead level of mediocrity." How differently we hear that expression used and to what different meanings does the last word lend itself. When it is replaced by its synonym middle, or mean, it is generally, or at least often, "the golden mean" that we speak of. But why golden? Why not leaden, iron, or aluminum? Surely because the qualifying adjective must imply some particular value, some especial worth in the eyes of the one who uses the word. It is evident that there can be but three general classes—those who are above the mean, those who have reached it, and those who have not; and we must admit that the latter class is the one from which so much has come, that it is in favor of this middle position. For there are many who undoubtedly believe that it is never right to be an extremist, or in fact hardly in advance, of the great majority. Are we then left to infer that most people belong to the third class? (for it is not necessary in a mathematical demonstration that a majority should agree with the average.) Surely the man who occupies a high position does not envy the man who holds a low one — at least for his position — and human nature is such that few men are satisfied with their present condition; so we are left to the conclusion that the present exalted place which the golden mean occupies in the popular mind is due to those who have not reached it.

Some would have us believe that in material things we should endeavor to reach this end at once and deposit everything in one general pile from whence it would be redistributed share and share alike. There might be a greater inducement than now exists, to try it, if there were any proof that things would not immediately tend to return to their former state. There is a fundamental rule in mathematics which states that things which are true all the way as they approach their limits are also true at the limits, and if we apply this to the same state of affairs that looks toward a golden mean in everything, what would be the result? Why then we must reason that if it is a good thing for men to have equal shares of money and land, it must also be good for them to share in other things. Well, suppose they did and every man had just so many suits of clothes (or it might in this case be only a fraction of a suit when every one had his share), so many pairs of shoes, so many hats, so many acres of land, and so many acres of water, in fact his portion of everything; what would be the result? Having a share in everything, what would he attempt to do at first, or at all, what could he do well; what could he be other than a jack-of-all-trades, and a poor one at that? (For we do not find many admirable Crichtons even in our day.) The result would be nothing less than stagnation—stagnation of the worst kind, for there could be no exchanges made, or the whole scheme would soon be nullified. It would be "the *dead* level of mediocrity."

Nature could not continue her work any more than man, if this rule be applied to her. There would be no power, no force, and no need of any, for the great plan of equalization would have left no room for further changes. A *difference* of temperatures is necessary before heat can be given and received, and when the final mean *is* reached for all the bodies in the universe, it will be a useless because a uniform temperature, and all natural things will settle down for a long, last sleep. Nature shows us that things were created with a difference, and observation leads us to the same conclusion about men. All civilization has tended to make man more dependent upon his fellow man and to emphasize the fact that the race has reached a point when men must separate if they would progress. That is, one man should not be content to plod along as he sees others doing, if he is able to pass them. Hamerton says that Leonardo da Vinci was the only man who came near having a complete education, but that such a person would be impossible to-day because the specialists have gone too far for him. In attainments at least it would be suicidal to attempt to follow him in our time, for the field has both widened and lengthened. Let there be distinctions (as there always will, however much we may declare there is not), for without, very much of the incentive for our best work is gone.

ORIGINAL, AND GOOD.

FROM a small pamphlet entitled "Something about Trombones" there is extracted a few interesting facts about this musical instrument, so intimately connected with the Moravian Church in Bethlehem. No one who has ever heard them can forget the weird sweetness of the music as it floats from the tower of the old church, marking the passage of some soul into the next world, or the tone of exultation with which they announce the early Easter morning. To the new student they are a surprise, and when as graduate he leaves the old town of Bethlehem there is still the memory of the trombones. The trombones seemed to have been used for the first time in 1754. Prior to this time the French horn and trumpet had been used both in church services and "in the harvest field on the opening of the joyous season of ingathering; on the the streets of the village in the early hours of Easter morning, and from the flat roof of the Single Brethren's House to announce the departure of souls to the eternal world." It is supposed that the sachbut mentioned in the Psalms of David was the prototype of the present trombone.

The word *trom-bo-ne* comes from the Italian, and means a large trump. The Moravian trombones were blown on the anniversary of the birth of King George II. On early Easter morning the trombones begin at about three o'clock and play at the corners of the principal streets. A service in the church is held, and just after service the congregation marches into the cemetery, to the eastern end, headed by the trombone choir, which is much larger on Easter morning than usual. At the rising of the sun the immense crowd of people disbands.

WHAT curious and odd things inhabit this section of Pennsylvania. The country has been so long settled that all the rubbish and litter of years has accumulated and can be seen by one who observes. The original Pennsylvania Dutchman has been father to many odd customs, and has left marks of his oddity in the numerous signs, guide posts, and toll bridges with which he has adorned the country. Every farmer who is supposed to be somebody boasts of a neatly painted sign nailed to the gate, "Beware of the dog," "This house for *sail*," or "Five hundred dollars fine for trespassing on these premises." A sign on a bridge at Coplay warns people not to smoke on the bridge or to carry fire across it in an open vessel. The same sign forbids the driving of more than a certain number of *hornet* cattle across the bridge at one time. It can only be surmised that hornet cattle were unpopular on account of their stings and were exterminated. A road running northward from Bethlehem has a branch road running westward to Catasauqua at every mile. One may drive along the north road all afternoon and will find that the guide boards at all the branch roads read, "Catasauqua 7 miles." The toll bridges are noted for that famous old legend, "No credit for tolls." Many a tramp has been prevented from pursuing his gentlemanly career by just such a sign.

Originally, the toll bridge at Freemansburg, now free, was owned by two women. They never slept, and woe to the person who attempted to cheat the argus-eyed spinsters out of a cent. Their cries and shrieks of rage and agony pursued him to his dying day. The days of toll bridges are numbered and will soon become part of the past. Made of wood, boarded over the top, and in many cases the sides enclosed, unpainted, shaky, and so lonely at night, they will soon be a mere memory.

IN the good old days of medical college life, when the students had to plunder the adjoining cemeteries for subjects, there lived a famous surgeon who was a practical joker. Passing along a quiet street late one night, he noticed a horse and carriage tied in front of a tavern. Sitting on the seat, holding the lines, was a very stiff and grave individual, who seemed to be almost too quiet. On closer inspection the surgeon discovered that the driver was a recent resident of some cemetery. He quietly took the subject off the seat and laid him in the gutter and, getting in, arranged himself in the same manner as he found his predecessor. In a few moments two medical students came out of the tavern feeling very happy over their recent success. They got in, one on either side of their driver, and started for the college. Very gently the surgeon passed one arm around each student and suddenly gave them a quick hug. With a yell that would have startled the dead they gave one leap from the moving carriage and put for home, leaving the surgeon much as he expected they would.

FOR LEHIGH MEN.

This column will contain, chiefly, such information in regard to addresses and occupations of Alumni as does not appear in the latest issue of the *Lehigh Register*. Please contribute.

THE SENIOR CIVIL TRIP.

ON Thurday afternoon, March 31, a party of Senior Civils, under the charge of Mr. Wilcox, left Bethlehem for a trip to Mauch Chunk, Athens, Wilkes-Barre, Hazleton, Drifton, and Stockton. The party consisted of Messrs. Asmussen, Baird, Cobb, Coleman, Gjertsen, Jiminez, Maurice, Millar, Olney, Rathbun, and Schneider. A stop of an hour was made at Mauch Chunk, giving the men an opportunity to see some of the bridges, and study the wearing of the rails on the fourteen-degree curve at the station.

Athens was reached at 10 P.M., Thursday evening. Early the next morning the drafting rooms of the Union Bridge Company were visited. Nearly an hour was spent in listening to explanations and in discussing the drawings of bridges in process of erection. Afterward, under the charge of Mr. Wilson, a slow and careful inspection was made of the immense shops. Particularly interesting was the process of forging heads on some of the largest eye bars that have ever been made. From the forging shops to the machine shop, where the pin-holes in the eye bars are cut out and then reamed to the proper size; from there to the larger machine shops, where rivet holes were being drilled and shoes planed; then to the immense shop where riveting, punching, shearing, planing, and constructing were all going on at once; steam, hydraulic, and pneumatic riveters were seen in operation, machines for planing the ends of girders, rows of drilling machines, massive shears, all striving to produce the bridge that had existed before only on paper; thence to the yards, where the workmen were assembling some unsymmetrical structure that had no two floor beams alike.

Afterward the entire party proceeded to the residence of Mr. Maurice of the Bridge Company, where a short reception was held by Mrs. Maurice, followed by a very dainty luncheon. Very reluctantly "goodbyes" were said, when the party proceeded to the testing room to see a special, full-sized test of an eye bar. The testing machine having a capacity of 600 tons seemed capable of breaking almost anything, but beside it lay an eye bar from the famous Forth Bridge which it could not master. The entire party tendered to Mr. Wilson their hearty thanks for the more than interesting day they had spent with him.

Wilkes-Barre was reached Friday evening and early on Saturday morning proceeded to Drifton, where they were met by Mr. Wagner, '85, who showed and carefully explained, by drawing, the immense iron coal breaker, so well known to mining engineers. The breaker was inspected from top to bottom and many new and interesting things were seen by the civil engineers.

A short walk brought them to Mr. Eckley B. Coxe's library, containing the library of Weisbach, the famous German experimenter. The laboratories were next visited and at 10.30 the party left for Hazleton, after having visited Mr. Coxe for a few moments.

At Hazleton Mr. L. Emmerich, '82, took the party out to Stockton to visit a famous coal stripping. After explaining the lay of the coal measures and the general plan of the workings, Mr. Emmerich conducted them into the mines, where the process of coal mining was well shown.

From Stockton the party walked to a small station called Lumber Yard, where a train was taken, reaching Bethlehem at 8.20 P.M., ending the most instructive and delightful trip ever taken by Lehigh men. It is desired in this crude way to thank those who did so much to make the trip one long to be remembered, and to show them that the memory of it all is still fresh in their minds.

PERIODICAL AND BOOK NOTES.

[A continuation of the list published on page 59 of Vol. I, No. 1, of THE QUARTERLY.]

A continuous key to the abbreviations of the names of periodicals can be found in Vol. I. The following is added: National Car and Locomotive Builder, published in New York City; abbreviated, "Nat. Car and Loco. Build." Articles marked * are continued through two or more numbers of the periodical; those marked † are in the form of short communications.

INDEX TO SUBJECTS FROM TECHNICAL PERIODICAL LITERATURE.

Additional Terms in the Great Inequalities of Jupiter and Saturn. Astron. Jour., Oct. 10, '91.

Adjustable Control of Church Gas Lights. Eng. Build. Rec., Jan. 16, '91.

Aerodynamics, D. S. P. Langley's Experiments in. Sci. Amer., Feb. 13, '92.

Alabama Coal Fields, Economical Review of. Proc. Eng. C. of Phila., July, '91.

Alcohol in Beers, Note on Dabaries' Process for the Indirect Estimation of. Analyst, Jan., '92.

Algebraic Proof of a Certain Series, On the. Am. Jour. Math., Oct. '91.

Alloys of Tin and Titanium, The. Iron Age, Mar. 24, '92.

Alpha and Beta Naphthol, A Ready Method of Distinguishing Between. Am. Jour. Phar., Mar., '92.

Alternate Current Measurement, The Principles of. Elec'n, Dec. 18, '91.

Alternate Current Motors. Elec. World, Mar. 5, '92.

Alternating Current Machines, Some Curves from. Elec'n, Nov. 27, '91.

Alternating Currents of High Frequency, Tesla's Experiments with. Elec. World, Mar. 26, '92.

Alternating Currents of High Potential and Frequency, Mr. Tesla's Lectures on. Nature, Feb. 11, '92.

Alternating Currents, Some Experimental Investigations of. Elec'n, Feb. 26, '92.

Alternating Currents, Some Phases of. Elec. World, Jan. 23, '92.

Alternating Electrical Systems and their Physical Hazzards. Sci. Am. Sup., Feb. 6, '92.

Alternating Sparking Distances. Elec'n., Dec. 25, '92.

Aluminum, The Present Status of. Sci. Am. Sup., Jan. 9, '92.

Aluminum, The Specific Heat of. Jour. Frank. Inst., Feb., '92; Iron, Mar. 11, '92, and Chem. News, Feb. 26, '92.

Aluminum, The Use of. Am. Mach., Feb. 20, '92.

Aluminum, On the Action of Certain Liquids on. Sci. Am. Sup., Mar. 5, '92.

Aluminum Sulphide, Process of and Apparatus for Preparing. Sci. Am. Sup., Feb. 6, '92.

Aluminum, The Chemical Analysis of. Jour. Anal. and Ap. Chem., Jan. '92.

American High Speed Engine, The. Iron Age, Mar. 3, '92.

Aneroid in Hypsometry, The. Nature, Feb. 11, '92.

Angustura Back, False. Am. Jour. Phar., Mar., '92.

Annealing, A Non-Oxidizing Process of. Eng. Min. Jour., Jan. 9, '92 and Iron, Jan. 29, '92.

Antifebrin, and Phenacetin Derivatives, On the Action of. Am. Jour. Phar., Feb. '92.

Antimony Smelting, The English Process of. Eng. Min. Jour., Mar. 12, '92, and Iron, Feb. 19, '92.

Application of Electricity to the Drilling of Metals. Elec'n, Jan. 22, '92.

Application of Elliptic Functions to a Problem in Geometry. Annals of Math., Jan., '92.

*Application of Weston Volmeters and Ammeters to Practical Measurements. Elec. World, Mar. 26, '92.

A Practical Experiment. Scribner's, Mar., '92.

Atlantic Liner, Past, Present, and Future. Sci. Am. Sup., Jan. 16, '92.

Areas in Land Surveying, A New Method of Calculating. Jour. Ass'n Eng. Soc., Dec., '91.

Armor Tests and Developments. Sci. Am. Sup., Jan. 16, '92.

Armor Trials, The. Sci. Am. Sup., Jan. 16, '92.

Aromatic Formyl Compounds, On some Derivatives of. Am. Chem. Jour., Dec., '91.

Asbestos in Filtration, The Use of. Jour. Anal. and Ap. Chem., Jan., '92.

Astronomical Theory of the Glacial Period, The. Nature, Jan. 28, '92.

Astronomy, New Chapter in the Warfare of Science, Part I. Pop. Sci. Mo., Mar., '92.

Atomic Weights. Sci. Am. Sup., Apr. 2, '92.

Atomic Weights, Relations Between. Chem. News, Mar. 11, '92.

Attempts to Invent a New Motor. Amer. Mach., Mar. 10, '92.

Austrian Bridge Regulations. Jour. Ass'n. Eng. Soc., Nov., '91.

Azomide, N. H.—The New Sodium Salt—The Most Highly Explosive Substance Known. Sci. Am. Sup., Jan. 9, '92.

Bacteria in our Dairy Products. Pop. Sci. Mo., Apr., '92.

Bacterium which Ferments Starch and Produces Amyl Alcohol, A. Am. Jour. Phar., Mar., '92.

Bad Air and Bad Health. Pop. Sci. Mo., Apr., '92.

Barium Peroxide, The Behavior of with Metallic Salts. Chem. News, Mar. 11, '92.

*Bearing Materials—Chemistry Applied to Railroads, XXV. R. R. and Eng. Jour., Feb., '92.

*Bearing Metal Alloys. Jour. Frank. Inst., Feb. '92; Nat. Car and Loco. Build., Mar., '92, and Eng. News, Mar. 26, '92.

Benzene, Action of on Benzal Chloride in the Presence of Aluminum Chloride. Am. Chem. Jour., Dec., '91.

Bessel's Functions of the Second Kind. Annals of Math., Jan., '92.

*Betfer Wood Construction. Am. Arch., Feb. 13, '92.

Bitangential of the Quintic. Annals of Math., Oct., '91.

Blast Furnace Slag. Eng., Feb. 19, '92.

Blast Furnace Slags, The Disposal and Utilization of. Iron, Feb. 12, '92, and Iron Age, Mar. 10, '92.

*Blast Furnace Slags—Their Calculation by Graphic Methods. Iron Age, Feb. 25, '92.

Block Signal, What is a? Eng. News, Feb. 6, '92.

Boric Acid and a New Boric Preparation. Am. Jour. Phar., Feb., '92.

Brake Tests, Recent. Nat. Car and Loco. Build., Mar., '92.

Brake Tests, The Lehigh Valley. Eng. News, Feb. 27, '92.

*Bridge Building, A Short History of. Eng., Jan. 1, '92, and Eng. Build. Rec., Jan. 30, '92.

Bridge Details. R. R. Gazette, Feb. 26, '92.

Bridge Legistation. Jour. Ass'n. Eng. Soc., Nov., '91.

Bridge Strains, German Practice in Computing. Eng. News, Feb. 27, '92.

Bursting Pressure of Cylindrical Boilers, The. Sci. Am. Sup., Mar. 26, '92.

Business Aspects of Pharmacy, The. Am. Jour. Phar., Feb., '92.

Butter Adulterant, Estimation of. Jour. Anal. and Ap. Chem., Dec., '91.

*Cable Motive Power, Report on the Progress of. Eng. Build. Rec., Feb. 20, '92.

Calcium Phosphate, Composition of Artificial Crystals of. Jour. Anal. and Ap. Chem., Dec., '91.

Calorimeters for Locomotive Use, Steam. R. R. Gaz., Jan. 22, '92.

Camphor: Methods of Growth and Manufacture in Formosa. Jour. Anal. and Ap. Chem., Feb., '92.

Candle Power of Incandescent Lamps as Related to Current, Voltage and Energy Consumed. Elec'n, Dec. 4, '91.

Candy, How it is made. Sci. Am. Sup., Feb. 27, '92.

*Capitals. Am. Arch., Feb. 27, '92.

Capture of Comets by Planets. Astron. Jour., Dec. 9, '91.

Car Couplers, The Strength of. Iron Age, Mar. 17, '92.

Car Heating by the Acetate of Soda Method. Sci. Am. Sup., Feb. 6, '92.

Caustic Soda, Action of on Wood. Sci. Am. Sup., Feb. 13, '92.

Caustic Soda and Chlorine Electrolytic Process. Elec'n, Jan. 8, '92.

Centrifugal Force and Resulting Phenomena. Sci. Am. Sup., Feb. 27, '92.

Centrifugal Force, Effect of on the Transmitting Power of Driving Ropes. Proc. Eng. C. of Phila., Jan., '92.

*Centrifugal Ventilators. Eng., Mar. 4.

Certain Space and Surface Integrals. Annals of Math., Oct., '91.

Chemistry of Paints and Painting, The. Nature, Jan. 14, '92.

Chlorine Gas and Soda by the Electrolytic Process. Sci. Am. Sup., Feb. 13, '92.

Chronophotography, or Photography as Applied to Moving Objects. Nature, Jan. 7, '92.

Climate, The Modification of Our. Sci. Am. Sup., Feb. 16, '92.

Climate, Variation in. Pop. Sci. Mo., Apr., '92.

Coal Consumption of Locomotives. Nat. Car and Loco. Build., Mar., '92.

Coal Gas: Its Manufacture, Distribution, and Consumption (A Series of Articles for Gas Students). Jour. Gas Light, Mar. 8, '92.

Cobalt in Manganese Ores, The Determination of, and a Quick Method for its Estimation. Chem. News, Feb. 12, '92.

Codeine Sulphate, Note on. Am. Jour. Phar., Mar., '92.

Coffee-Leaf Tea. Am. Jour. Phar., Feb. '92.

Color in Photography. Sci. Am. Sup., Jan. 30, '92.

Color in Photometry. Sci. Am. Sup., Feb. 27, '92.

Coloring Matter Produced by Bacteria in Medicinal Distilled Waters, On Certain Soluble. Chem. News, Feb. 19, '92.

Combined Resistance of Conductors in Parallel, The. Elec'n., Dec. 18, '91.

Comet, 1891 I. Astron. Jour., Oct. 18, '91.

Commercial Resin of Scammony. Am. Jour. Phar., Mar., '92.

Comparative Photometric Tests of Large Gas Burners and Lanterns for Public Lighting. Jour. Gas Light, Jan. 26, '92.

Comparative Value of Gas, Water, and Steam for Supply of Motive Power. Jour. Gas Light, Feb. 9, '92.

Compound Locomotive, Hungarian State Railway. Eng. News, Feb. 20, '92.

Compound Locomotive, Johnstone's Double Truck, Mexican Central Ry. Eng. News, Mar. 12 and 26, '92.

Compound Locomotives. R. R. Gaz., Jan. 15, '92.

Compound Locomotives, A Sketch of the History of. R. R. Gaz., Feb. 19, '92.

Compound Locomotives for Fast Passenger Service—C. R. R. of N. J., Vanelain. R. R. Gaz., Feb. 12, '92.

Compound Locomotives in Freight and Passenger Service. R. R. Gaz., Jan. 1, '92.

Compound Locomotives, Practical Tests of. Sci. Am. Sup., Jan. 23, '92.

Compound Locomotivês, Vauclain Four-Cylinder. Eng. News, Feb. 20, '92.

Computation of Places in Eccentric Ellipses and Hyperbolas. Astron. Jour., Jan. 12, '92.

Comstock, The Silver Mines of. Eng. Min. Jour., Jan. 9, '92.

Comstock Lode, The Discovery of the. Eng. Min. Jour., Jan. 16, '92.

Conical Pistons. Eng., Feb. 12, '92.

Condensers in Electric Lighting, Probable Future of. Elec'n, Jan. 1, '92.

Condenser Spark and Air Jet, Further Experiments with. Elec. World, Feb. 27, '92.

Construction of Locomotive Boilers. Eng. News, Jan. 30, '92.

Construction of Theoretical Indicator Diagrams for Compound Engines. Eng. Mar. 18, '92.

Consumption of Water and Use of Meters. Eng. News, Jan. 16, '92.

Cores for Moulding Steam Cylinders in Dry Sand. Am. Mach., Jan. 21, '92.

Cotton Industry in Brazil, The. Pop. Sci. Mo., Mar., '92.

Couplers, Strength of Master Car Builders. Eng. News, Mar. 5, '91

*Construction. Am. Arch., Jan. 16, '92.

Curved Dams, The Theory of. Proc. Eng. C. of Phil., July, '91.

Curves of the Fourth Degree, A Pair of, and their Application in the Theory of Quadrics. Am. Jour. Math., Oct., '91.

Cut-Outs, Individual Arc Lights and Motor. Elec. World, Feb. 27, '92.

†Cylinder Condensation. Eng., Mar. 4, 11 and 18, '92.

Cylinder Condensation in Steam Engines, A Thermo-electric Method of Studying. R. R. and Eng. Jour., Feb., '92.

Cylinder Oils. Sci. Am. Sup., Jan. 16, '92.

Cylinders for Compound Locomotives, Proportions of. R. R. Gaz., Jan. 15, '92.

Damping of Electrical Oscillations on Iron Wires. Elec'n, Jan. 8, '92.

Darwinism in the Nursery. Pop. Sci. Mo., Mar., '92.

Déformation des Surface, Sur un Problème a la. Am. Jour. Math., Oct., '91.

Designing Mechanical Movements. Am. Mach., Mar. 10, '92.

Detection and Determination of Potassium Spectroscopically. Jour. Anal. and Ap. Chem., Jan., '92.

Dialyzer, A Rapid. Jour. Anal. and Ap. Chem., Jan., '92.

Diazo Compounds, Decomposition of. Am. Chem. Jour., Jan., '92.

Differential Equation $\Delta u + k^2u = 0$, Pockets on the. Annals of Math., Jan., '92.

Digestive Ferments, Influence of Temperature on. Am. Jour. Phar., Feb., '92.

*Discharge of Electricity Through Exhausted Tubes without Electrodes. Elec'n, Nov. 6, '91.

Distribution of Power by Alternating Currents, Notes on. Elec. World, Feb. 6, '92.

Distribution of Power by Direct Currents. Elec. World, Feb. 6, '92.

Discharge of Steam Through Orifices, Experiments on the. Proc. Eng. C. of Phila., July, '91.

Dissipation of Energy Through Reversals of Magnetism in the Core of a Transformer. Elec'n, Dec., 4, '92.

Domestic Animals of India. Pop. Sci. Mo., Mar., '92.

Dust and Fresh Air: How to Keep Out the one and Let In the other. Am. Arch., Mar. 5.

Dynamo Machines. Sci. Amer., Jan. 16, '92.

Dynamos, Determination of the Efficiency of. (In Series.) Elec. World, Feb. 29, '92.

Eclipses and Chronology. Astron. Jour., Nov. 7, '92.

Edison Dynamo and Motor, How to Make an. Sci. Am. Sup., Mar. 5, '92.

Effects of Nascent Hydrogen and Nascent Oxygen on Nitric Acid. Am. Chem. Jour., Dec., '91.

"Eggio:" A Preparation of the Yolk of Eggs, Analysis of. Jour. Frank. Inst., Mar., '92.

Electrical Distribution, Development of. Elec'n, Feb. 5, '92.

Electrical Transmission of Power. Proc. Eng. C. of Phila., Jan., '92.

Electric Block Signal on N. Y. Central & Hudson River R. R. Elec. World, Jan. 23, '92.

Electric Current Curves. Elec'n., Nov. 20, '92.

Electric Horse-Power Curves, Herzog's. Elec. World, Mar. 26, '92.

Electric Horse-Power Distribution. Sci. Am. Sup., Jan. 16, '92.

Electric Lighting of French Battle-Ship "Marceau." Elec. World, Jan. 23, '93.

Electric Railway of Buda-Pesth, The. Jour. Frank. Inst., Feb., '92.

Electric Metal Working. Iron Age, Jan. 28, '92.

Electricity in Agriculture. Sci. Am. Sup., Feb. 13, '92.

Electricity in Horticulture. Sci. Am. Sup., Feb. 13, '92.

Electricity in Relation to Science. Pop. Sci. Mo., Feb., '92.

Electricity to Metallurgy, Modern Application of. Iron, Jan. 22, '92.

Electro-Chemical Equivalent of Copper, On the Apparent Variation of the. Elec'n, Nov. 6, '92.

Electrodynamic Theories and the Electromagnetic Theory of Light. Nature, Feb. 18, '92.

Electrolytic Determination of Metals as Amalgams, Notes on the. Am. Chem. Jour., Dec., '91.

Electrolytic Separations. Jour. Anal. & Ap. Chem., Feb., '92.

Electro-Magnetic Disturbance at Great Distances, Detection of. Elec'n, Nov. 27, '92.

Electro-Magnetic Machinery, Notes on. (In a series of papers.) Jour. Frank. Inst., Mar., '92.

Electrotechnical Notations, Abbreviations and Symbols. Elec'n, Jan. 15, '92.

Elementary Ironless Dynamo. Elec'n, Feb. 26, '92.

Elementary Thermodynamics. Nature, Feb. 4, '92.

Elliptique Fonctions, Sur une Expression Nourelle des, par le Quotient de deux Series. Am. Jour. Math., Oct. '91.

*Engineering Schools of the O. S., The. Eng. News, Mar. 19, '92.

English and American Locomotives. Amer. Mach., Feb. 18, '92.

English Bye-Ways. Am. Arch., Mar. 12, '92.

Estimate of Material and Labor on Large Reverberatory Furnaces for Smelting Copper. Eng. Min. Jour., Jan. 16, '92.

Ether Waves and their Actions, Views of. Elec'n, Feb. 19, '92.

"Extra Current" on Breaking, Value of. Elec'n, Dec. 18, '92.

Fat Extraction and Fat Calculation in Milk Analysis. Analyst, Nov. '91.

Fat in Milk, The Estimation of. Analyst, Nov. '91.

Floods in the Susquehanna River, Report on. Eng. Build. Rec., Jan. 23, '92.

*Flora of Northern Ohio, On the. Am. Jour. Phar., Mar., '92.

Foundations and Floors for the Buildings of the World's Columbian Exposition. Jour. Ass'n. Eng. Soc., Dec., '91.

French Roads, Their Administration, Construction, and Maintenance. Jour. Ass'n. Eng. Soc., Jan., '92, and LEHIGH QUAR., Jan., '92.

*Fuel Gas: Its Production and Distribution. Jour. Gas Light, Jan. 19, '92.

Functions log (4) and e^x, On Independent Definitions of the. Am. Jour. Math., Oct., '91.

Gas Analysis. Jour. Gas Light, Feb. 2, '92.

Gas Engine Economy, Eng., Feb. 12, '92.

Gas Engine for Electric Lighting Stations. Eng., Feb. 12, '92.

Gas vs. Steam for Motive Power. Jour. Gas Light, Feb. 16, '92.

General Law Applicable to Gases and Liquids, A. Chem. News, Mar. 11, '92.

Glaser Method for the Determination of Iron and Alumina, Notes on. Chem. News, Jan. 29, '92.

Grate Area. Elec'n, Mas. 18, '92.

"Great Eastern," The Last of the. Elec'n, Jan. 15, '92.

Harmonie Analysis of Transformer Curves, The. Elec'n, Jan. 22, '92.

Heat Balance of the Blast Furnace. Eng. Min. Jour., Jan. 30, '92.

Heating of Conduits by Electric Currents, The. Elec'n, Dec. 4, '92.

Hertz Oscillations. Elec'n, Mar. 4, '92.

High Electrical Resistance, On a Differential Electrostatic Method of Measuring. Elec'n, Feb. 26, '92.

High Potential Electricity. Am. Mach., Mar. 3, '92.

High Potential Transmission. Elec. World, Mar. 26, '92.

Horse Power of Boilers, The. Am. Eng., Feb. 18, '92.

Hydrogen Peroxide, Action of Upon Metallic Salts. Am. Jour. Phar., Mar., '92.

Hyoscynamine Gold Chloride, On the Crystalline Form of. Am. Jour. Phar., Mar., '92.

*Hysteresis, On the Law of. Elec. World, Jan. 30, '92, and Elec'n, Feb. 12,' 92.

Illuminating Flames. Jour. Gas Light, Feb. 23, '92.

*Illuminating Flames. Chem. News, Mar. 4, '92, and Sci. Am. Sup., Apr. 2, '92.

Incandescent Gas. Am. Arch., Feb. 6, '92.

Indigo-blue, Some New Products from. Chem. News, Mar. 11, '92.

Indexing Drawings. Am. Mach., Jan. 28, '92.

Indian Meteorology. Nature, Jan. 7, '92.

Indicator Diagrams, Some Peculiar. Am. Mach., Mar. 17, '92.

Indigenous Drugs, Analysis of Some. Am. Jour. Phar., Feb. and Mar., '92.

"Inductance," Meaning of the Term. Elec'n, Jan. 16, '92.

Induction by High Potential Discharges. Elec. World, Feb. 10, '92.

Induction Coil for Spectroscopic Work, Improved form of. Chem. News, Feb. 19, '92.

Infants' Food. Am. Jour. Phar., Mar., '92.

Influence of Time in Testing Various Metals, The. Iron, Mar. 18, '92.

Inks, Examination of. Chem. News, Feb. 5, '92.

Insulated Conductors for Electric Lighting and Other Purposes, On the Specificatians of. Elec'n, Dec. 11, '91.

Insulating Materials, The Behavior of Under the Actioc of High Potential Differences. Elec'n, Mar. 18, '92.

Insulation of Electric Wires and Cables, The. Elec'n, Dec. 18, '92.

Involuntary Movements. Pop. Sci. Mo., Apr., '92.

Interior Wood Work. Am. Arch., Jan. 23, '92.

Involute Bevel Gear Teeth, Limiting Numbers of. Am. Mach., Feb. 4, '92.

Iodine Number for Lard Oil by the Hube Method. Chem. News, Jan. 22, '92.

Iodine in Chloroform, Solubility of. Am. Jour. Phar., Feb.. '92.

Iodine, Note on Volumetric Solution of. Am. Jour. Phar., Feb., '92.

Ipecacuanha, The Value of the Unofficial Parts of. Am. Jour. Phar., Mar., '92.

Iron and Aluminum in the Presence of Phosphoric Acid, The Estimation of. Jour. Anal. & Ap. Chem., Dec. '91.

*Iron and Aluminum in the Presence of Phosphoric Acid, The Estimation of. Chem. News, Feb. 5, '92.

*Iron, Notes on the Manufacture of. Iron, Mar. 4, '92.

Iron with Bichromate of Potash and Stannons Chloride, Volumetric Determination of. Jour. Anal. & Ap. Chem., Jan., '92.

Is Man the Only Reasoner? Pop. Sci. Mo., Feb., '92.

Iso-anilides, Researches on the. Am. Chem. Jour., Dec. '91.

Isogonol Transformation, Note on. Annals of Math., Jan. '92.

Isomorphism and Composition of Thorinus and Uranous Sulphates. Am. Chem. Jour., Jan., '92.

Jacket Cores for Moulding Steam Cylinders. Am. Mach., Feb. 18, '92.

Kid Gloves, The Manufacture of. Sci. Am., Jan. 30, '92.

"Lamp," the Electric Light Station Manager, and the "Customer." Elec. World, Mar. 19, '92.

Lancashire Boilers, On Some Details in the Construction of Modern. Elec'n, Nov. 13, '91.

*Land-locked Navigation from Long Island Sound to the Mississippi River. Proc. Eng. C. of Phila., July, '91.

Language of Animals, New Observations on the. Pop. Sci. Mo., Feb., and Sci. Am. Sup., Feb. 13, '92.

Large Power Units in Electrical Work, The Economic Limits of. Elec'n, Dec. 11, '91.

†Laws of Steamship Propulsion. Eng., Feb. 26, '92.

*Lightning Arresters, and the Discovery of Non-arching Metals. Elec. World, Jan. 16, '92.

Lightning, Some Curious Caprices of. Elec. World, Jan. 16, '92.

Limitations of Electric Power Transmission. Eng. Min. Jour., Mar. 19, '92.

Linear Transformation, A Note on. Am. Jour. Math., Oct. '91.

Linseed Oil and other Oils used in Art Painting. Sci. Am. Sup., Mar. 5, '92.

Liquid Fuel Burning Locomotive on the Great Eastern Railway of England. R. R. Gaz., Feb. 26, '92.

*Living Protoplasm, On Chemism in. Chem. News, Jan. 8, '92.

Locomotive Boilers. Nat. Car & Loco. Build., Feb. '92.

Locomotive Boilers. Sci. Am. Sup., Feb. 20, '92.

Locomotive Counterbalance, Notes on. Nat. Car & Loco. Build., Mar., '92.

Locomotive Driving Springs, Formulæ for the Deflection of. Proc. Eng. C. of Phila., July, '91.

Locomotives for High Speeds, Notes on. Nat. Car & Loco. Build., Jan., '92.

Longitudinals vs. Cross-ties for Railway Tracks. Trans. Am. Soc. Cir. Eng., Dec. '91.

Long Submarine Cables, The Determination of the Capacity of. Elec'n, Feb. 5,'92.

Low-Pressure Networks, Extension of. Elec'n, Jan. 8, '92.

Lubricating Oils, A Rapid Method of Determining the Composition of. Chem. News, Jan. 15, '92.

Magnetic Field, An Early Conception of. Jour. Frank. Inst., Mar., '92.

Magneto-Thermo-Electric Experiments. Elec'n, Feb. 15, '92.

Manganese and Sulphur in Pig Iron. Iron, Mar. 18, '92.

Marsupial Mole, The Australian. Pop. Sci. Mo., Mar., '92.

Matter Thrown up During the Submarine Eruption North-West of Pantellera, Oct., 91. Nature, Jan. 14, '92.

Measurement of Sag Between two Alternating Currents. Elec. World, Mar. 26, '92.

Mechanical Equivalent of Heat, Experiments to Obtain. Jour. Frank. Inst., Feb., '92.

Mechanical Rubber Goods, How Made. Sci. Am. Sup., Feb. 12, '92.

Mechanics, Some Illustrations of. Eng., Mar. 11, '92.

*Melting Points of Minerals, Determination of the. Chem. News, Jan. 8, '92.

*Metallic Arsemides, The Oxidation of by the Electric Current. Chem. News, Jan. 29, '92.

Micro-Organisms in Pharmaceutical Preparations. Am. Jour. Phar., Feb., '92.

Mild Steel, Cold Bending Tests of. Eng. Build. Rec., Mar. 5, '92.

*Mild Steel for Structural Purposes II, Basic Steels in Germany. Eng. News, Jan. 9, '92.

Migration of the Semminy. Nature, Jan. 14, '92.

Milk Tests, Investigation of. Jour. Anal. and Ap. Chem., Feb. '92.

Molybdenum, On the Determination of. Chem. News, Feb. 19, '92.

Multivalent and Univalent Involutory Correspondence in a Plane Determined by a Net of Curves of the n^{th} Order. Am. Jour. Math., Oct., '91.

Musical Instruments—Orchestral. Pop. Sci. Mo., Apr., '92.

Musical Instruments—The Organ. Pop. Sci. Mo., Mar., '92.

Musical Instruments—The Piano-forte. Pop. Sci. Mo., Mar., '92.

Naphthaline in Illuminating Gas. Jour. Gas Light, Jan. 19, '92.

New Astronomy: Its Methods and Results. Sci. Am. Sup., Feb. 27, '92.

New York Harbor, Improvement of the Entrance to. Eng. News, Mar. 19, '92.

Nitric Ethers, The Decomposition of by Alkaline Solutions. Am. Chem. Jour., Dec., '91.

"Nitrogen Free Extract," Upon Certain Constituents of the. Chem. News, Jan. 22, '92.

Nitrogen, Report on the Determination of. Chem. News, Feb. 26, '92.

Nitrohydric Acid. Chem. News, Jan. 8, '92.

Non-inductive Resistance, Construction of. Elec. World, Feb. 13, '92.

Normal and Hissing Arcs. Elec. World, Mar. 19, '92.

Oceanic Causeways, Recent. Pop. Sci. Mo., Feb., '92.

Oil of Turpentine, Some Experiments on the American. Jour. Anal. & Ap. Chem. Jan., '62.

Oleoresius. Am. Jour. Phar., Mar. '92.

One Hundred Miles an Hour. (An Editorial Criticism of Forney's and Ely's Articles in March Scribner's.) Eng. News, Mar. 18, '92.

†Pressure Gauges for High Pressure Gases. Eng., Jan. 29 and Feb. 26, '92.

Proper Motions of 27 Southern Stars. Astron. Jour., Jan. 29, '92.

Propagation of Induced Magnetism in Iron, The Rate of. Sci. Am. Sup., Jan. 30, '92.

Proportion in Steam Engine. Am. Mach., Feb. 4, '92.

Proposed Methods of Transmittting Power from Niagara Falls to Chicago. Elec. World, Feb. 20, '92.

Proposed Ship Canal between New York and Philadelphia, Connecting the Delaware and Raritan Rivers. Jour. Frank. Inst., Mar., '92.

Proteids of the Corn or Maize Kernel, A Study of the. Am. Chem. Jour., Dec., '91.

Puddling, The Theory of. Iron, Jan. 8, '92.

Pumping Dredge, Use of by the Norfolk Company. Proc. Eng. C. of Phila., July, '91.

Purifying Water, Some Means of. Sci. Am. Sup., Feb. 13, '92.

Pursha Tridentata, D. C. Am. Jour. Phar., Feb., '92.

Rates of Propagation of Electro-Magnetic Waves, Experimental Determination of. Elec'n, Nov. 27, '91.

*Radiation of Electric Energy. Elec'n., Nov. 27, '91.

Railway Traffic, American and English. Eng., Jan. 1, '92.

*Recognition of Sulphides, Aisenides, Antimonides and Double Compounds of these Bodies with Metals, Rapid Method for the Accurate. Chem. News, Jan. 22, '92.

Red Rock Cantilever Bridge. Trans. Am. Soc. Civ. Eng., Dec., '91.

Relation Between Rise of Temperature and Current in Electric Conductors. Elec. World, Feb. 27, '92.

Reverbatory Smelting for Copper, Improvements in. Eng. Min. Jour., Jan. 9, '92.

Riveted Joint Diagrams. Eng. New, Feb. 6, '92.

Roads. Sci. Am. Sup., Feb. 27, '92.

Rolling Friction, Experimental Determination of in Operating the Thames River Bridge, together with Methods for Determining Power to Operate Draw Bridge. Trans. Am. Soc. Cir. Eng., Dec., '91.

Rolling Mills, The Evolution of the American. Nat. Car & Loco. Build., Jan., '92.

Rotating Currents, Note on. Elec'n, Dec. 18, '92.

Rotating Magnetic Field, Notes on the Production of a. Elec'n, Jan. 8, '92.

Rubber Pattern Work. Am. Mach., Feb., 18, '92.

Safety Apparatus for Drying Explosives in Vacuum. Sci. Am. Sup., Jan. 2, '92.

Sand and Stone Used for Cement Mortar and Beton. Eng. News, Mar. 26, '92.

Sand Feed Apparatus for Locomotives. Eng. News, Feb. 13, '92.

Sapotin: A New Glucoside. Am. Chem. Jour., Dec., '91.

Science and Fine Art. Pop. Sci. Mo., Apr., '92.

Salts of Chronium, Action of Heat on Solutions of. Chem. News, Jan. 8, '92.

*Secondary Batteries. Elec'n, Dec. 4, '91.

Secondary Batteries. Sci. Am. Sup., Jan. 23, '92.

Sections and Mechanical Conditions of Car Wheels. Sci. Am. Sup., Jan. 23, '92.

Selection of Iron Ores, Limestones, and Fuels for the Blast Furnace, Notes on the. Eng. News, Feb. 20, and Iron, Feb. 26, '92.

Sanega, Northern. Am. Jour. Phar., Mar., '92.

Separation of Iron, Manganese and Calcium by the Acetate and Bromine Methods. Jour. Anal. and Ap. Chem., Feb., '92.

Sewage Disposal at Isolated Houses. Am. Arch., Mar. 12, '92.

Siemens Cable Transformer, The. Elec'n, Nov. 27, '91.

Siemens Electrolytic Process for the Extraction of Copper from its Ores. Eng. Min. Jour., Mar. 19, '92.

Silica, Determination of in Substances Containing Fluorine. Analyist, Jan., '92.

Sims-Edison Torpedo. Sci. Am. Sup., Mar. 5, '92.

Size and Speed of the Steamship of the Future. I. Age, Feb. 18, '92.

†Sizes of Pulleys for Wire Ropes. Eng., Feb. 19 and 26, '92.

Sliding Surfaces in Machine Tools, A Chapter in the. Am. Mach., Mar. 17, '92.

Small Motors, Comparative Working Expenses of. Jour. Gas Light, Feb. 2, '92.

Smokeless Boiler, The Schulz-Knandt. I. Age, Feb. 18, '92.

Smokeless Powders. I. Age, Mar. 3, '92.

Solar Specteoscopy, What Constitutes it? Sci. Am. Sup., Jan. 2, '92.

Solid Dielectric and the Residual Charge, On the Structure of a. Elec'n, Feb. 5, '92.

Solutions, Percentages in. Am. Jour. Phar., Feb., '92.

Solid Formulæ; Models for Use in Teaching Organic Chemistry. Am. Chem. Jour., Dec., '91.

Soft Steel in Bridges. Proc. Eng. C. of Phila., Jan., '92.

Some Comparisons as to the Relative Value of Solid, Liquid, and Gaseous Fuel. Proc. Eng. C. of Phila., Jan., '92.

Some Secondary Battery Experiments. Elec'n, Jan., 92.

Specifications. Am. Mach., Mar. 26, '92.

Spectrum of Iron and the Periodic Saw. Nature. Jan. 14, '92.

*Spectrum of Iron and the Periodic Saw. Iron, Jan., 22, '92.

Speed in Locomotives (3 articles). Scribner's, Mar., '92.

Speed in Trains, Apparatus for Measuring. Eng. News, Mar. 5, '92.

Spiral Weld Tube Machinery, The Development of. Jour. Frank. Inst., Mar., '92.

*Standard Sleeping Car—Pullman's Palace Car Co. Nat. Car and Loco. Build., Jan., '92.

*Standard Volt and Ampere-Meter used at the Ferry Works, Thames Ditton, Description of the. Elec'n, Nov. 20, '92.

Starting Power of Large and Small Wheel Locomotives. Sci. Am. Sup., Jan. 9, '92.

Steam Formulæ. Proc. Eng. C. of Phila., July, '91.

Steam Turbines. Eng. News, Feb. 27, '92.

Steel in Bridge Construction, The Use of. Iron, Feb. 19 and 26, '92.

Stilts and Stilt-Making. Pop. Sci. Mo., Feb., '92.

Street Cleaning at Wachington, D. C., Notes on. Proc. Eng. C. of Phila., July, '91.

Stresses in Locomotive Tires. R. R. Gaz., Jan. 22, '92.

Stress in Cylinders. Am. Mach., Feb. 4, '92.

Structure and Chemistry of Flames, The. Jour. Gas Light., Jan. 12, '92.

*Submarine Cable Work, Notes on. Elec'n, Feb. 12, '92.

Sugar and Tannin in Wines, Estimation of. Am. Jour. Phar., Feb., '92.

Sulphuric Acid Solutions, Density of. Chem. News, Jan. 8, '92.

Sulphurs in Slags, Notes on the Determinarion of. Jour. Anal. and Ap. Chem., Feb., '92.

Sulphur, On the Estimation of. Jour. Anal. and Ap. Chem., Jan., 92.

Sulphur, The Quantitative Determination of. Jour. Anal. and Ap. Chem., Jan., '92.

Sun-Spots and Air Temperature. Nature, Jan. 21, 92.

Supposed Secular Variation of Latitude. Astron. Jour., Jan. 29, '92.

†Superheated Steam. Eng., Feb. 26 and Mar. 4, 11, and 18, '92.

Surface Gauge, A Remarkable. Am. Mach., Feb. 4, '92.

Sykes Block Signal System between Yonkers and Ossawana, N. Y. Cent. & H. R. R. R., The. Eng. News, Jan. 23, '92.

Symmetric Functions, Fourth Memoirs on a New Theory of. Am. Jour. Math., Oct., '91.

*Terra-Cotta Roofing-Tiles, On the older Forms of. Am. Arch., Mar. 26, '90.

Telephone Transmitter without Electrodes, A. Elec'n, Jan. 8, '92.

The Great Earthquake of Port Royal, Pop. Sci. Mo., Apr., '92.

Thermal Emissivity of Thin Wires in Air. Elec'n, Dec. 4, '91.

Thermo-Electric Standard of E. M. F., A. Elec'n, Dec. 25, '91.

The Term "Horse Power." Am. Engr. Feb. 20, '92.

Thin Coal Seams, Notes on the Running of in Missouri and Kansas. Eng. Min. Feb. 18, '92.

Titanic Oxide, Distribution of on the Surface of the Earth. Chem. News, Feb. 5, '92.

Titration of Zinc with Potassium Ferro-Cyanide in an Ammoniacal Solution. Jour. Anal. and Ap. Chem., Jan., '92.

Torpedo Net Protection. I. Age, Feb. 18, '92.

Train-Speed a Question of Transportation. Scribner's, March, '92.

Transformers, The Relation of Size and Efficiency in. Elec. World, Mar. 5, '92.

Transmission of Explosions across Air-gaps, Experiments on the. Jour. Gas Light, Feb. 9, '92.

Transmission of Power. Eng. News, Mar. 19, '92.

Transmission of Power by Electricity. Elec. World, Jan. 30, '92.

Trillium, An Analysis of. Am. Jour. Phar., Feb. '92.

Try-Phenyl-Methane and Chloroform, The Reaction between in the Presence of Aluminium Chloride. Am. Chem. Jour., Dec., '91.

Truck Bolsters, Strength of. Nat. Car and Loco. Build., Jan., '92.

Tunneling, A Method of. Sci. Amer., Jan. 23, '92.

Twenty-Four Knot Steamers. Sci. Am. Sup., Feb. 13, '92.

Universal Correspondence, Research on the Existence of. Am. Jour. Math., Oct., '91.

Universe of Stars, The. Pop. Sci. Mo., Feb., '92.

University Extension, Nationalization of. Pop. Sci. Mo., Feb., '92.

Utilizing Niagara Falls, A Canadian Project for. Sci. Am. Sup., Jan. 9, '92.

Utilizing the Water Power of Niagara Falls. Sci. Amer., Mar. 5, '92.

Vander Waal's Isothermal Equation. Nature, Jan. 24, '92.

Vanilla, on Commercial Extract of. Am. Jour. Phar., Feb., '92.

*Variable Stars, Contributions to the Knowledge of. Astrom. Jour., Feb. 13, '92.

Variable Stars, Observations of at the Observatory of Upsala. Astron. Jour., Jan. 29, '92.

*Variations of Latitude. Astron. Jour., Nov. 7, '91.

Variations of Latitude, and the Observations with the Washington Prime-Vertical Transit, On the Periodical. Astron Jour., Dec. 23, '91.

Volatile Compounds Containing Nickel and Iron. Eng., Mar. 18, '92.

Water Power Computations Worked out by the Slide Rule. Eng. Min. Jour., Jan. 9, '92.

Water Power, The Value of. Am. Mach., Feb. 25, '92.

Water Route from Chicago to the Ocean. Scribner's, Mar., '92.

Waterway between the Great Lakes and the Atlantic Seaboard, An Enlarged. Jour. Ass'n Eng. Soc., Dec., '91.

Wave Motion Model. Nature, Feb. 11, '92.

Wayside Optics. Pop. Sci. Mo., Mar., '92.

Welding by the Electric Arc. Elec'n, Dec. 25, '91, and Elec. World, Jan. 16, '92.

Weston Direct-reading Alternating and Continuous Current Voltmeter. Elec'n, Jan. 25, '92.

White Pepper, On the Adulteration of. Anal., Dec., '91.

White Pepper, Supplementary Note on the Analysis of. Anal., Feb., '92.

Winter Resistance of Trains. Sci. Am. Sup., Feb. 27, '92.

Wrought Iron and Steel. Am. Eng., Mar. 5, '92.

Yellow Pine Posts, Proposed New Formula for. R. R. Gaz., Jan. 29, '92.

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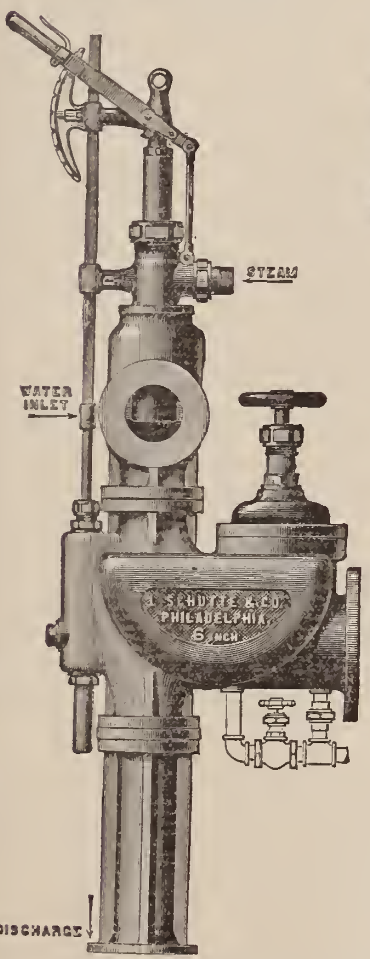

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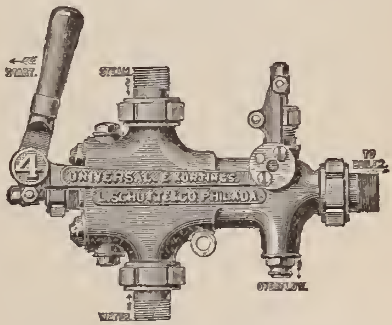

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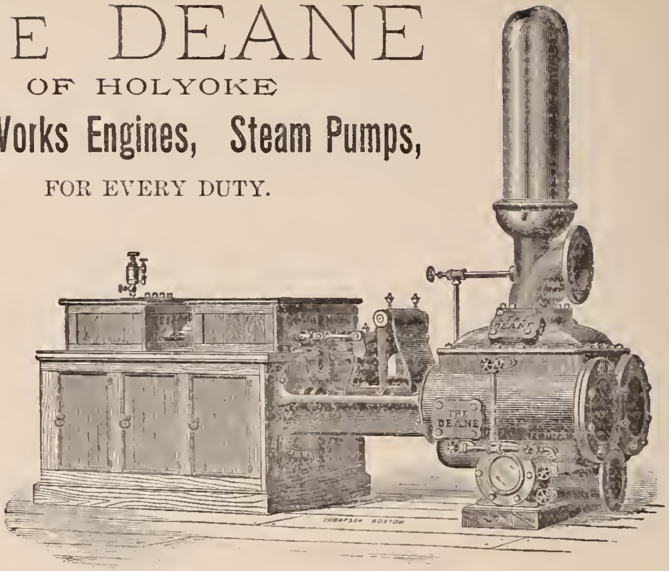

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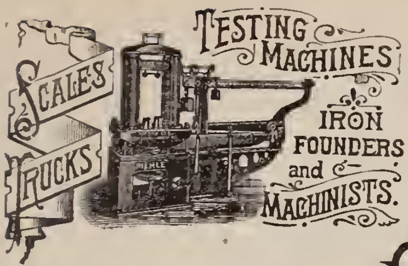

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